

WANAQUE GRADIENT  
CORROSION CONTROL  
REVIEW – INITIAL DRAFT

**City of Newark**  
Lead and Copper Rule Compliance Study  
Wanaque Gradient

Newark, NJ

DRAFT

City of Newark Department of  
Water and Sewer Utilities

February 1, 2019

**CDM  
Smith**

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# Section 1

## Introduction and Background

The City of Newark (Newark) supplies approximately 80 million gallons per day (mgd) of water to a population of over 300,000 customers located in Newark, NJ and its surrounding communities. Newark's population of approximately 280,000 receives water through a large, complex distribution system that is managed by the City of Newark's Department of Water and Sewer Utilities (Department).

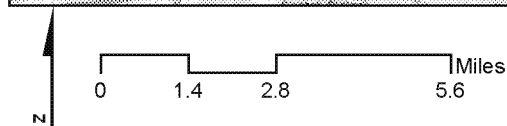
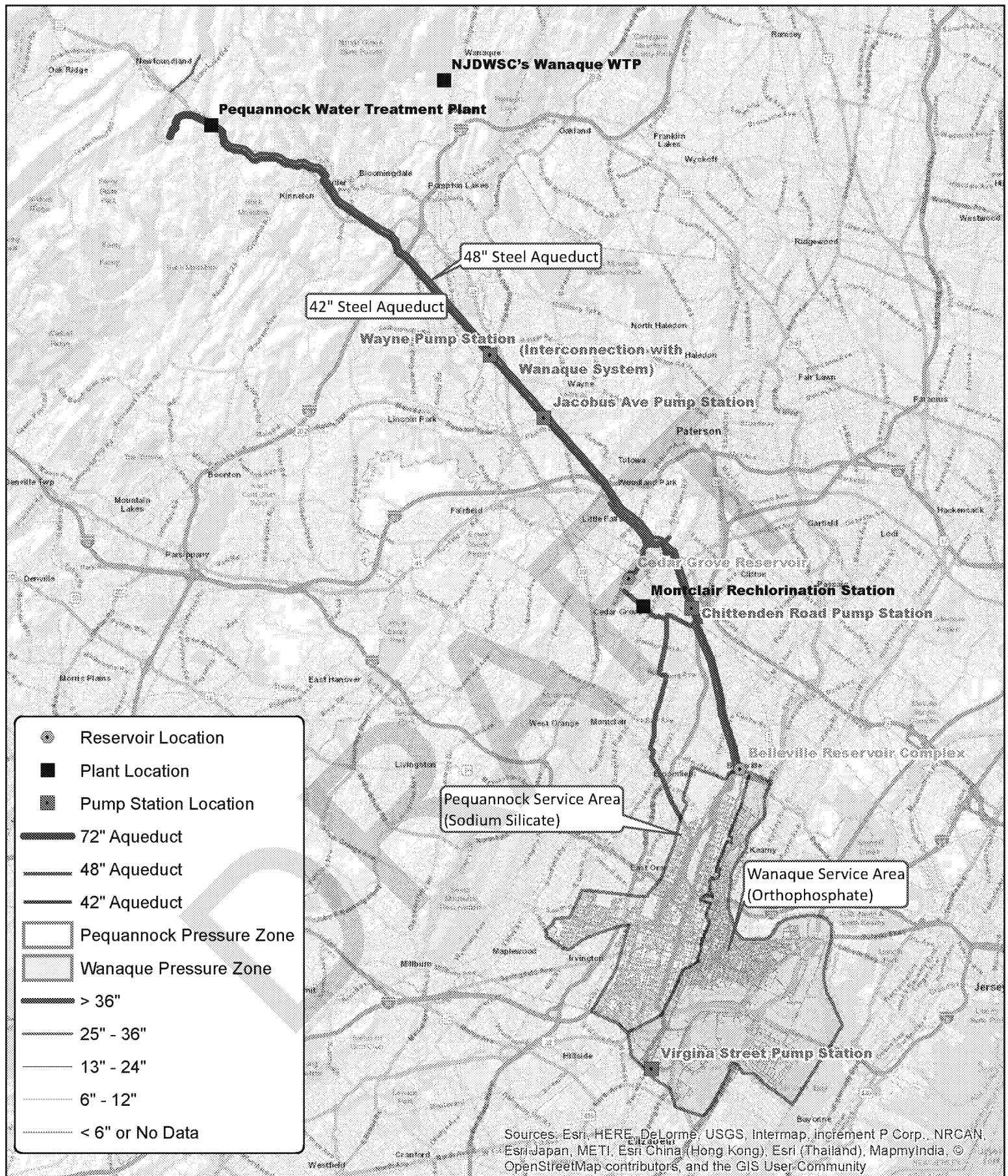
Newark utilizes two sources to supply their distribution system as shown on **Figure 1-1**. The Pequannock Water Treatment Plant (WTP), located in West Milford, NJ, supplies approximately 40 mgd primarily to Newark's West Ward and most of the North, South and Central Wards, or the "higher" pressure gradients above 200 feet. The Pequannock WTP treats surface water from the Charlotteburg Reservoir. Treated water flows from the Pequannock WTP through a 72-inch aqueduct which splits into dual 48-inch and 42-inch steel aqueducts to the uncovered, approximately 675 million-gallon (MG) Cedar Grove Finished Water Reservoir. The water then travels by gravity through the Valley Road Rechlorination Station in Montclair where it is rechlorinated prior to supplying Newark water distribution system's higher-pressure gradients.

The other water source for Newark is from the Wanaque WTP operated by the North Jersey District Water Supply Commission (NJDWSC), which supplies the East Ward, and portions of the North and Central Wards (pressure gradient of 165 ft and below) as shown in **Figure 1-1**. The Wanaque WTP utilizes conventional treatment with coagulation, clarification, and filtration and delivers water to Newark via two interconnections.

The first interconnection is through the Wayne Pump station, which typically delivers between 10 and 15 mgd of treated water from the Wanaque WTP to the Pequannock system upstream of the Cedar Grove Reservoir. The Wanaque supply that is blended with the Pequannock supply at this location does not receive a corrosion inhibitor before it is combined with Pequannock water.

Wanaque water is also supplied to Newark's lower pressure gradient (i.e. Wanaque Gradient) through a second interconnection at the Belleville Reservoir Complex at rates of approximately 25 to 28 mgd. Upstream of the Belleville Reservoir Complex, zinc orthophosphate is added for corrosion control.

During the January to June 2017 Lead and Copper Rule (LCR) sampling round, Newark exceeded the Action Level (AL) for lead at the 90<sup>th</sup> percentile, based on sample results taken at 233 residences. On July 11, 2017, the New Jersey Department of Environmental Protection (NJDEP) sent a letter to Newark that outlined a series of required actions in response to the AL exceedance. Of the requirements, NJDEP required Newark to submit an Optimal Corrosion Control Treatment (OCCT) recommendation in accordance with 40 CFR 141.82(a) no later than six (6) months after the monitoring period when the AL was exceeded, or by December 31, 2017.



In response to NJDEP, Newark submitted an OCCT Memorandum on December 27, 2017. The 2017 OCCT Memorandum outlined the following recommended actions:

- Continue to collect the Water Quality Parameter data
- Completion of a corrosion control optimization desktop study
- Undertake a coupon study at several locations in the distribution system
- Conduct pipe loop testing

The 2017 OCCT Memorandum proposed the following Water Quality Parameters (WQPs) to be maintained for the Pequannock system:

- pH over 7.2
- Alkalinity over 30 mg/L
- Silica over 6.0 mg/L as SiO<sub>2</sub>

Newark committed to increasing the sodium silicate dose to 12-15 mg/L from 8-12 mg/L, effective July 24, 2017.

The 2017 OCCT Memorandum also proposed the following WQPs to be maintained for the Wanaque Gradient in Newark's distribution system:

- pH over 7.2
- Alkalinity over 30 mg/L
- Orthophosphate above 0.4 mg/L as PO<sub>4</sub>-P (or 1.2 mg/L as PO<sub>4</sub>)

Optimal WQPs are typically established once corrosion control is optimized and after two consecutive 6-month follow-up WQP monitoring is performed showing compliance with the LCR. Since the 2017 OCCT Memorandum was issued, Newark has exceeded the lead AL in the second half of 2017 and both the first and second half of 2018. Therefore, Optimal WQPs have not yet been set by NJDEP.

In October 2018, the draft "Pequannock WTP Corrosion Control Review and Recommendations" prepared by CDM Smith provided the results of an evaluation of Newark's current corrosion control including an analysis of historic water quality and lead levels. The study indicated that an increase in lead levels since 2015 was occurring in the service area supplied by the Pequannock Gradient and not in the service area supplied by the Wanaque Gradient. Once this was determined, further analysis conducted for the October 2018 draft report focused on the Pequannock Gradient, including sequential sampling at customer homes and pipe scale analyses, to diagnose the cause of the increased lead levels.

Ultimately, it was concluded that the corrosion control treatment in the Pequannock system using sodium silicate was no longer effective for Newark's current water quality. As a result, protective scales, that had previously formed on lead service lines, were no longer providing corrosion

protection. It was also determined that flushing at the tap, a method generally accepted as a way for homeowners with lead service lines or lead-containing plumbing components to reduce exposure to lead in drinking water, was less effective for this particular situation. Furthermore, since the scale was unstable and could be easily disturbed, there was potential for releasing particulate lead into the water during flushing.

Newark is moving forward with the construction of a zinc orthophosphate feed system at the Valley Road Rechlorination Station that will benefit all residents served by Newark within the Pequannock Gradient. Zinc orthophosphate forms a protective barrier on lead service pipes and fixtures that contain lead and helps to reduce lead from leaching into the drinking water. In the interim, Newark has developed a program to distribute water filters and replacement cartridges to single family or multi-family homes in the Pequannock Gradient that have a lead service line or have interior plumbing comprised of copper piping with lead solder. Newark anticipates continued exceedances of the lead AL until the zinc orthophosphate can take effect, therefore, the filter distribution will continue until the zinc orthophosphate chemical is dosed into the drinking water and test results show lead levels decreasing in the system. In addition, Newark has increased its public education and awareness to notify residents of the lead levels found in older homes, particularly targeting those in higher risk categories.

On October 26, 2018, NJDEP provided comments on the October 2018 Pequannock draft report including requiring a more detailed corrosion control evaluation for the Wanaque Gradient, including sequential sampling, pipe scale analysis, and determining whether or not “elevated lead levels in the Wanaque Gradient can be attributed to the influence of Pequannock Gradient water leaking through division gates.” This report is a response to the first comment in NJDEP’s October 26, 2018 letter and focuses on the Wanaque water supply system to review the current corrosion control treatment and, if necessary, provide any recommendations for improvements.

As of January 29, 2019, results of several tests are pending, including the pipe scale analyses. This version of the report is an early draft of findings and the data included are still being vetted. The statements, data, findings and conclusions in this report may be updated or revised by the study authors.

## 1.1 Current Corrosion Control Treatment (CCT)

The Wanaque water supply system, operated by the NJDWSC, has dosed zinc orthophosphate in Totowa, upstream of their Belleville Reservoir Complex, since the mid-1990s. When the LCR was established in 1991, both the Pequannock and Wanaque Gradients showed evidence of high lead levels when performing the initial requisite monitoring programs in 1992 and 1993. At that time, both systems commenced corrosion control studies and implemented corrosion control treatment (CCT) in the mid- to late-1990s.

NJDWSC typically targets the following water quality at the Belleville Reservoir Complex: pH of approximately 7.8 to 8.0, orthophosphate residual of approximately 1.8 to 2.2 mg/L as PO<sub>4</sub>, and a free chlorine residual of 0.80 to 1.0 mg/L. NJDWSC supplies several communities with drinking water either on a regular or emergency basis, including Wayne, Cedar Grove, Bayonne, Kearny, Montclair, Ringwood, communities served by Passaic Valley Water Commission (PVWC), and Newark. Some of these communities are supplied with water upstream of the zinc

orthophosphate addition in Totowa, and add their own corrosion inhibitor, and some are supplied with water downstream of the zinc orthophosphate addition. Of all the water suppliers that are provided water by NJDWSC, only PVWC and Newark have experienced non-compliance with the LCR within the last 10 years. Both PVWC and Newark have other sources of water with separate treatment in addition to the water obtained through NJDWSC.

Water quality within the Newark distribution system supplied by Wanaque is discussed in Section 3.

## 1.2 Lead and Copper Rule Compliance Sampling Results

As noted above, due to consecutive rounds of lead AL exceedances in 1992 (90th percentile above the AL of 15 µg/L), both the Pequannock and Wanaque systems implemented CCT in the 1990s. After 1992, LCR compliance sampling was performed in 1998, 2002, 2003, 2006, 2009, 2012, 2015, 2017 and 2018 at residences throughout the City.

Maps showing the locations and lead concentration ranges for all compliance sampling events, including the initial sampling in 1992 leading to implementation of CCT, are provided in **Figures 1-2 through 1-13**. As shown in the figures, Newark experienced a period with very low lead concentrations at compliance sampling pool locations between 1998 and 2012. During this period, the compliance sampling locations varied by year and were not consistently representative of both the Pequannock and Wanaque supplies. For example, in 2002 and 2009, only homes receiving Wanaque water were sampled. In 1998 and 2006, only homes receiving Pequannock water were sampled. In 2015, slightly elevated lead concentrations were found, but they were still below the AL. Due to the significant increase in customer requested samples in 2018 (a total of 448 tested samples), the January to June 2018 and July to December 2018 graphs, **Figure 1-12** and **Figure 1-13** respectively, show both the results from the LCR compliance samples with verified pipe materials and the results from the customer requested samples that have not been verified and are not included in the 90th percentile calculation for LCR compliance. The LCR samples are identified as circles while the customer requested samples are identified as squares. Approximately 30 of the customer requested samples were listed under a different address than their account address. The locations are still being determined and will be added to the map for the final report.

Lead levels exceeded the AL during the first and second half of 2017, as well as the first and second half of 2018. The AL was also exceeded in the last three sampling rounds in Bloomfield, one of Newark's consecutive systems, which receives a large percentage of its supply from Newark's Pequannock WTP. As corrosion control chemistry transitions are a slow process, it cannot be determined exactly when the lead levels started to increase. To monitor the transition of lead levels, the acceptable practice is to maintain routine monitoring of the water quality parameters as well as continue tap sampling under the LCR. Newark is in compliance with the LCR by performing all required monitoring and actions triggered by a lead AL exceedance.

The LCR AL for copper is 1.3 mg/L at the 90th percentile value. Newark has not experienced high copper levels in their system based on the data analyzed other than one sample in the sequential sampling discussed in Section 4. Optimization of treatment for copper, therefore, is not addressed in this report.

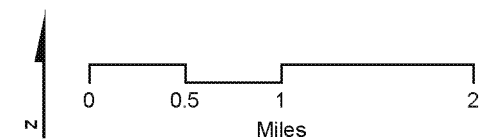
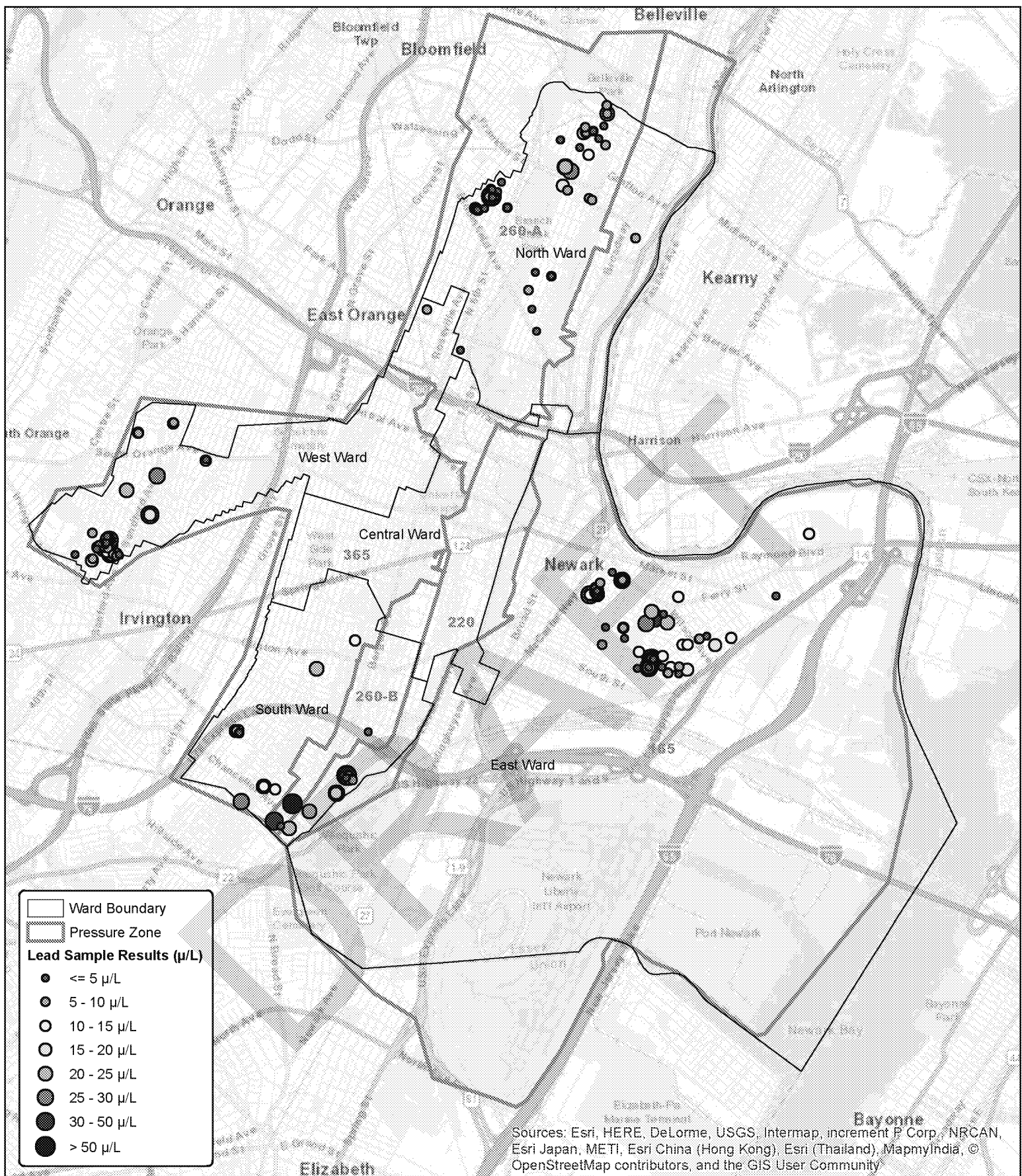
## 1.3 Wanaque WQP and Test Locations

Water Quality Parameters (WQPs) are monitored at sample locations throughout a distribution system and are used to regularly monitor conditions pertaining to corrosion control. The sample locations and WQPs are typically established by the water utility and approved by NJDEP. Optimal targets are set once a utility is in compliance with the LCR. Newark proposed target WQPs as stated earlier in this Section and has been monitoring their WQPs since July 2016 on a bi-weekly basis. The monitoring locations for Newark's WQPs are shown in **Figure 1-14**. According to the list, there are 13 WQP sampling sites in the Pequannock service area (labeled with "P") and 12 WQP sampling sites in the Wanaque service area (labeled with "W"). However, based on the addresses provided for these sample locations, it appears that the following WQP sampling sites may need to be updated:

- 7W – Labeled as Wanaque but appears to be located in the Pequannock service area
- 8W – Labeled as Wanaque but appears to be located in the Pequannock service area
- 11W – Labeled as Wanaque but appears to be located in the Pequannock service area
- 10P – Labeled as Pequannock but appears to be located in the Wanaque service area

Therefore, these WQPs were evaluated based on their actual physical location and not their number designation for the water quality evaluations presented in Section 3. The sample locations are being further investigated to confirm which system they are currently monitoring.

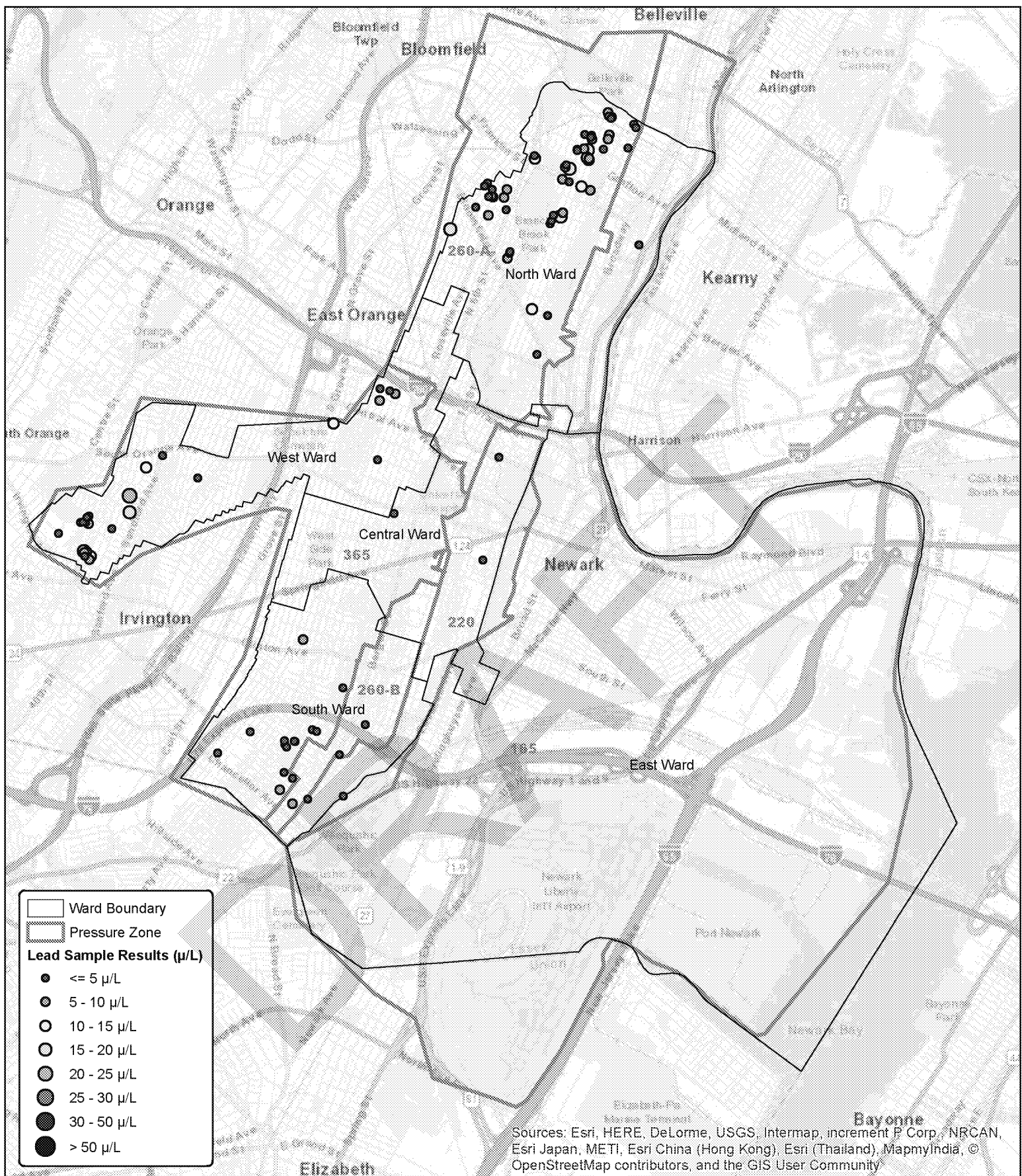




## Lead Level in the City of Newark

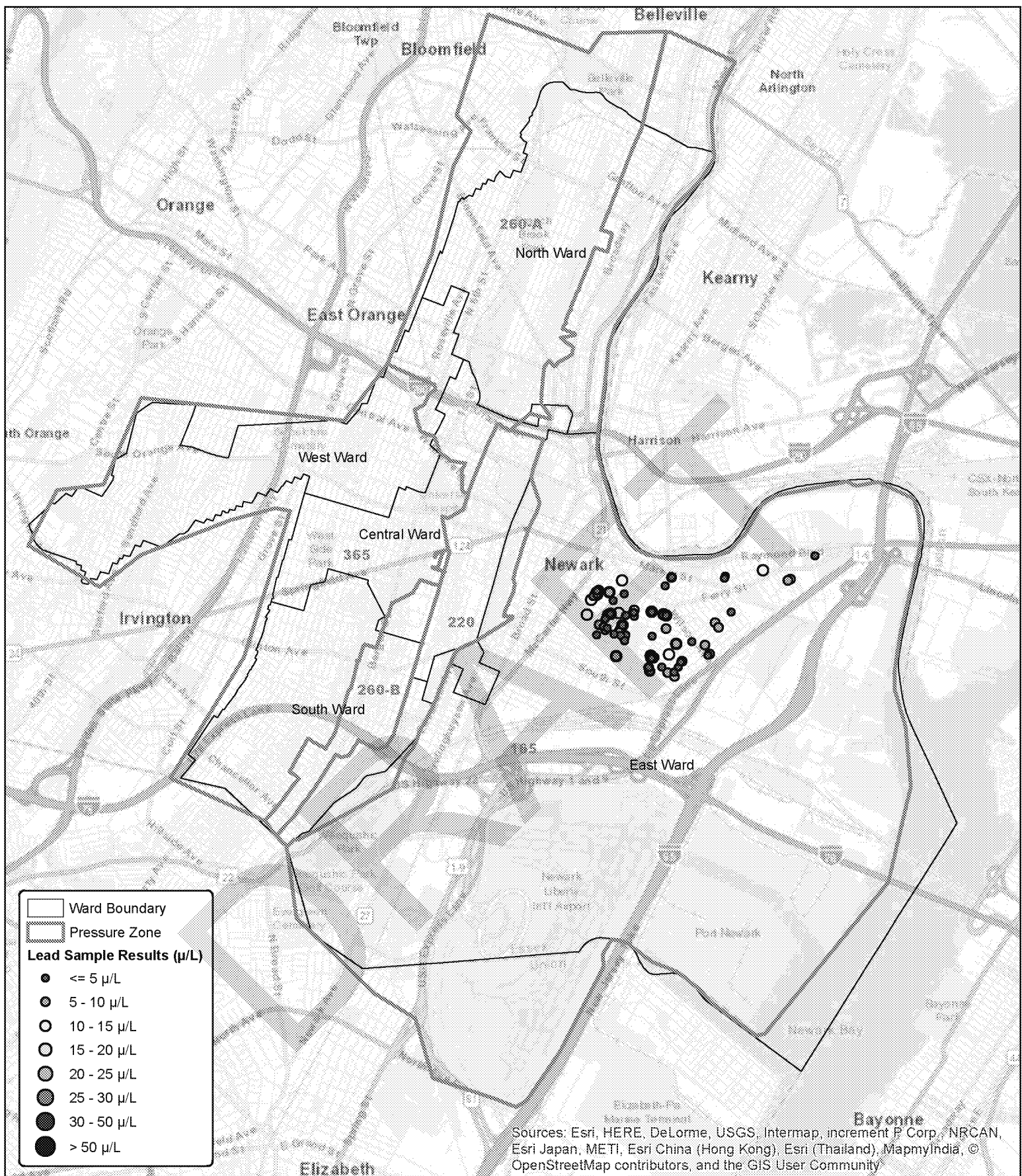
Data Collected: 1992

Figure 1-2



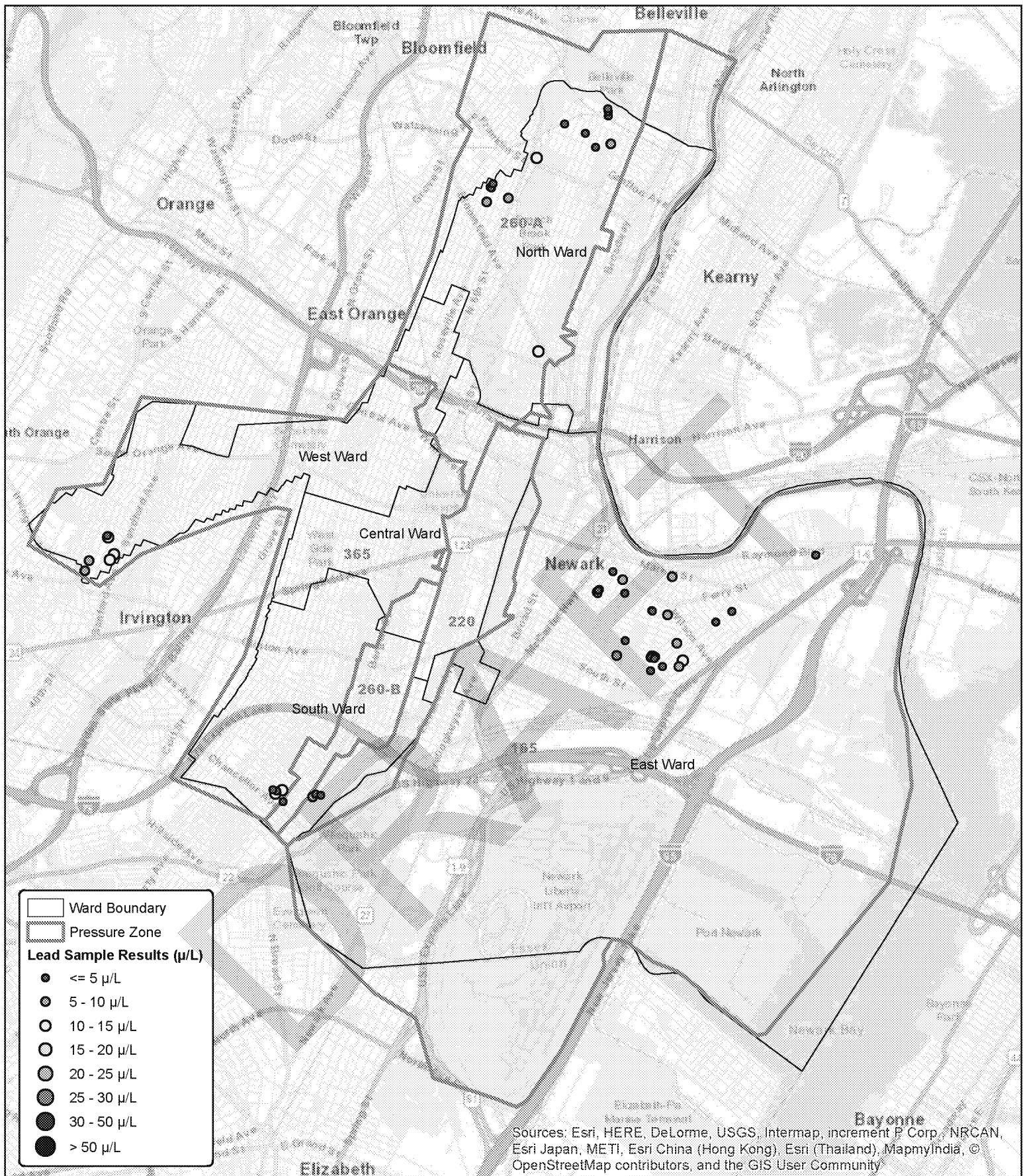
## Lead Level in the City of Newark

Data Collected: 1998



## Lead Level in the City of Newark

Data Collected: 2002

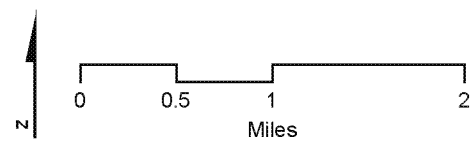
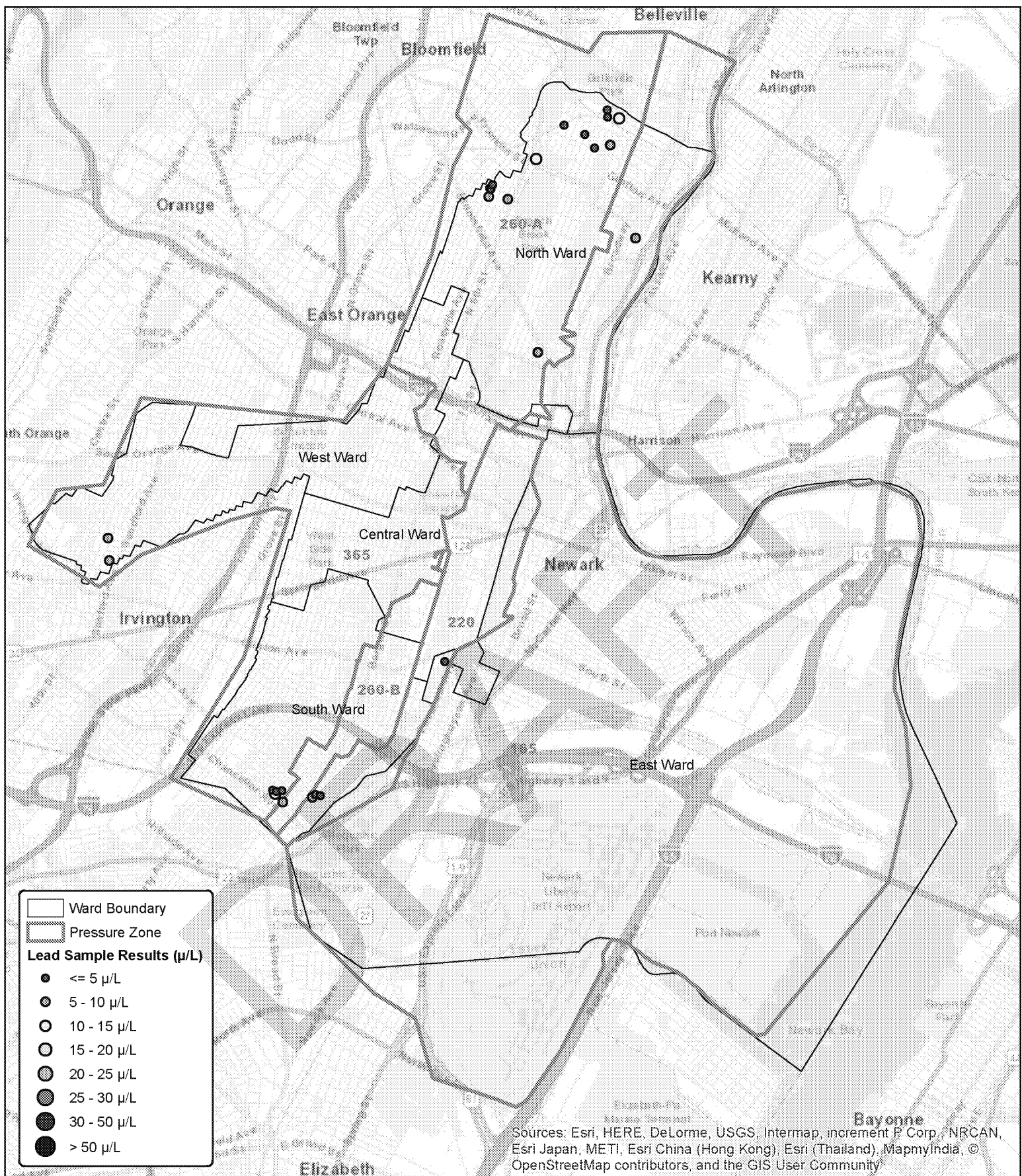


## Lead Level in the City of Newark

Data Collected: 2003

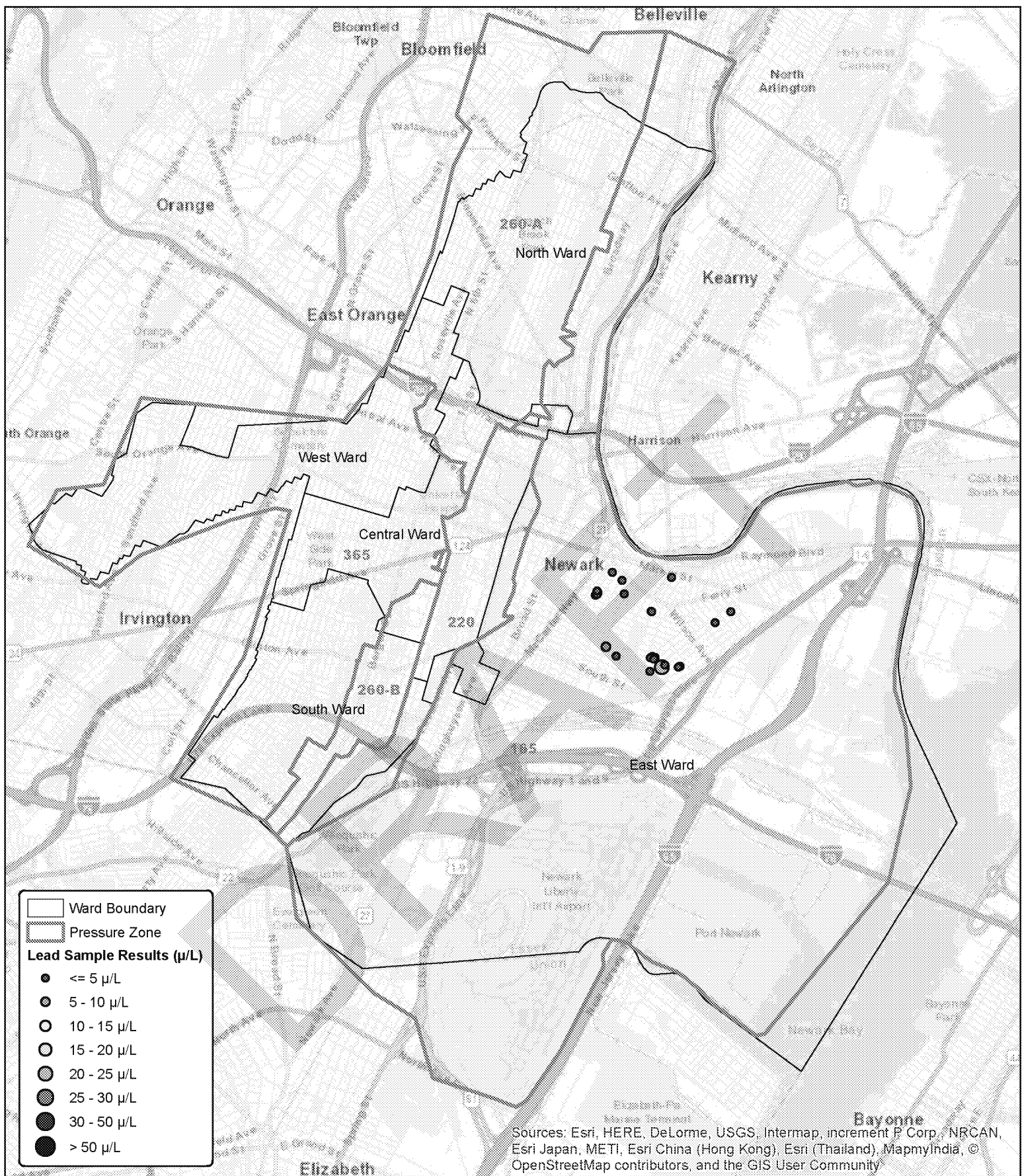
Figure 1-5





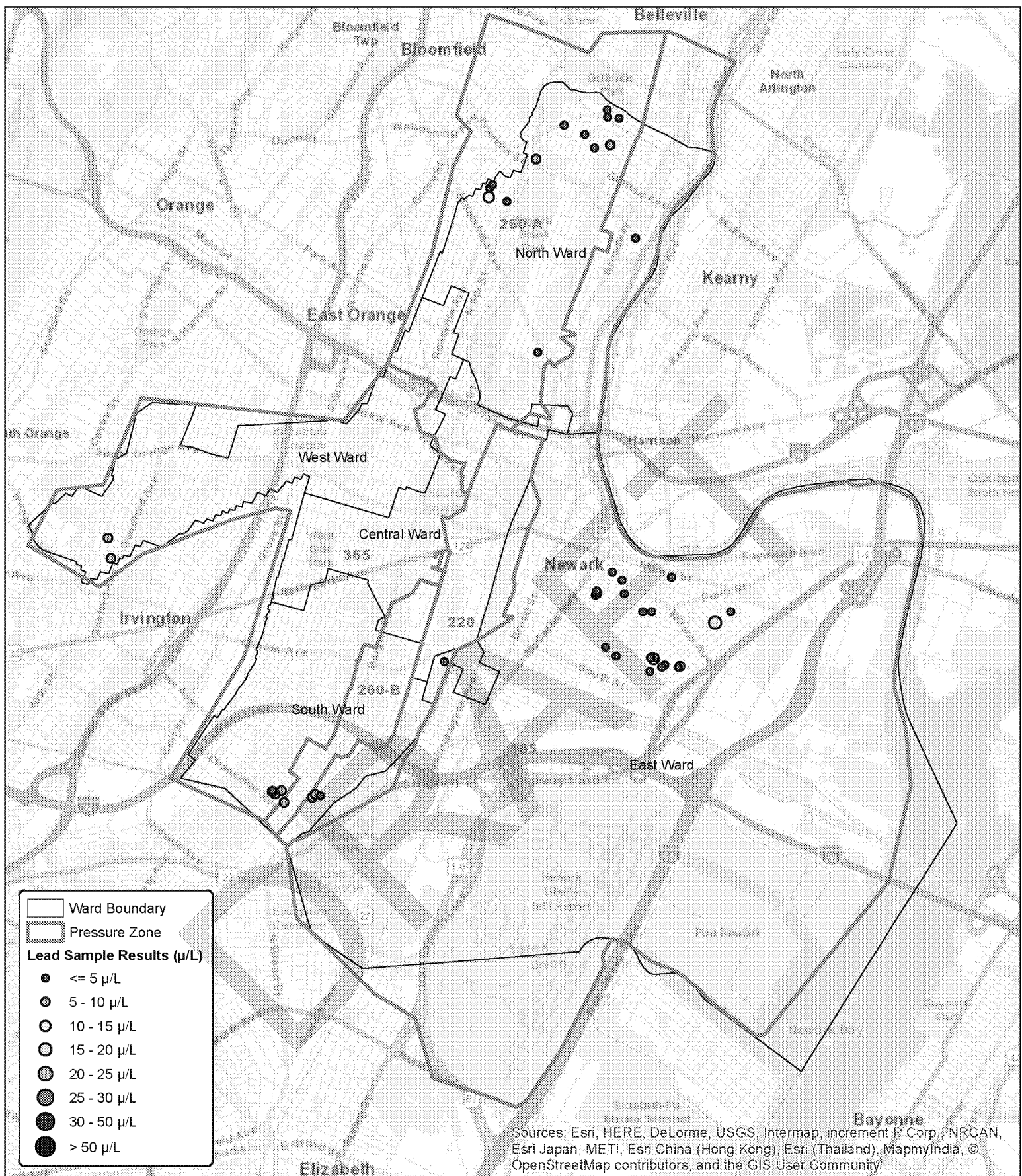
## Lead Level in the City of Newark

Data Collected: 2006



## Lead Level in the City of Newark

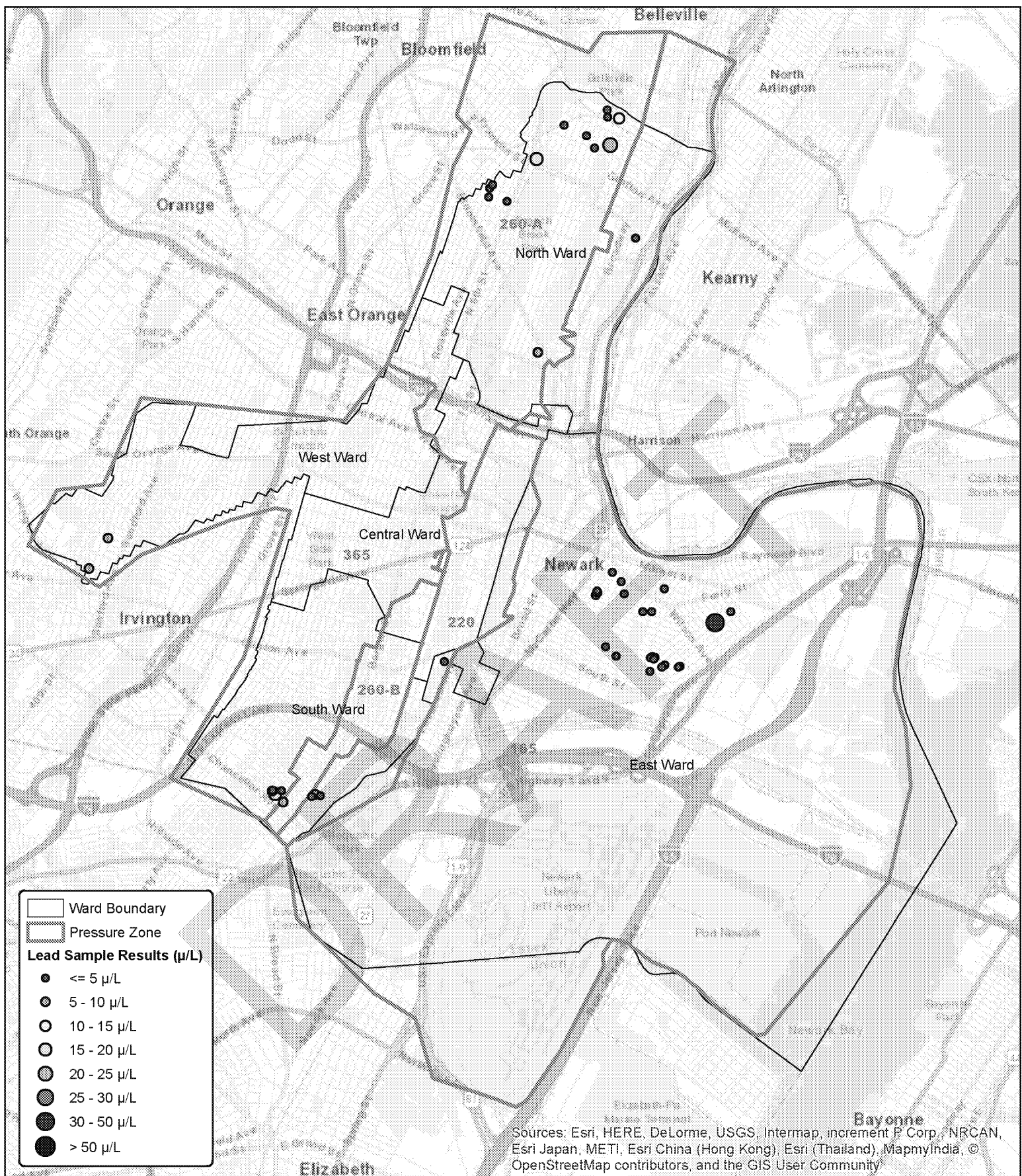
Data Collected: 2009



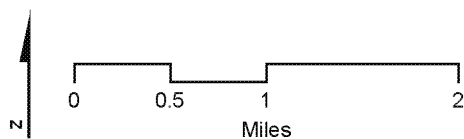
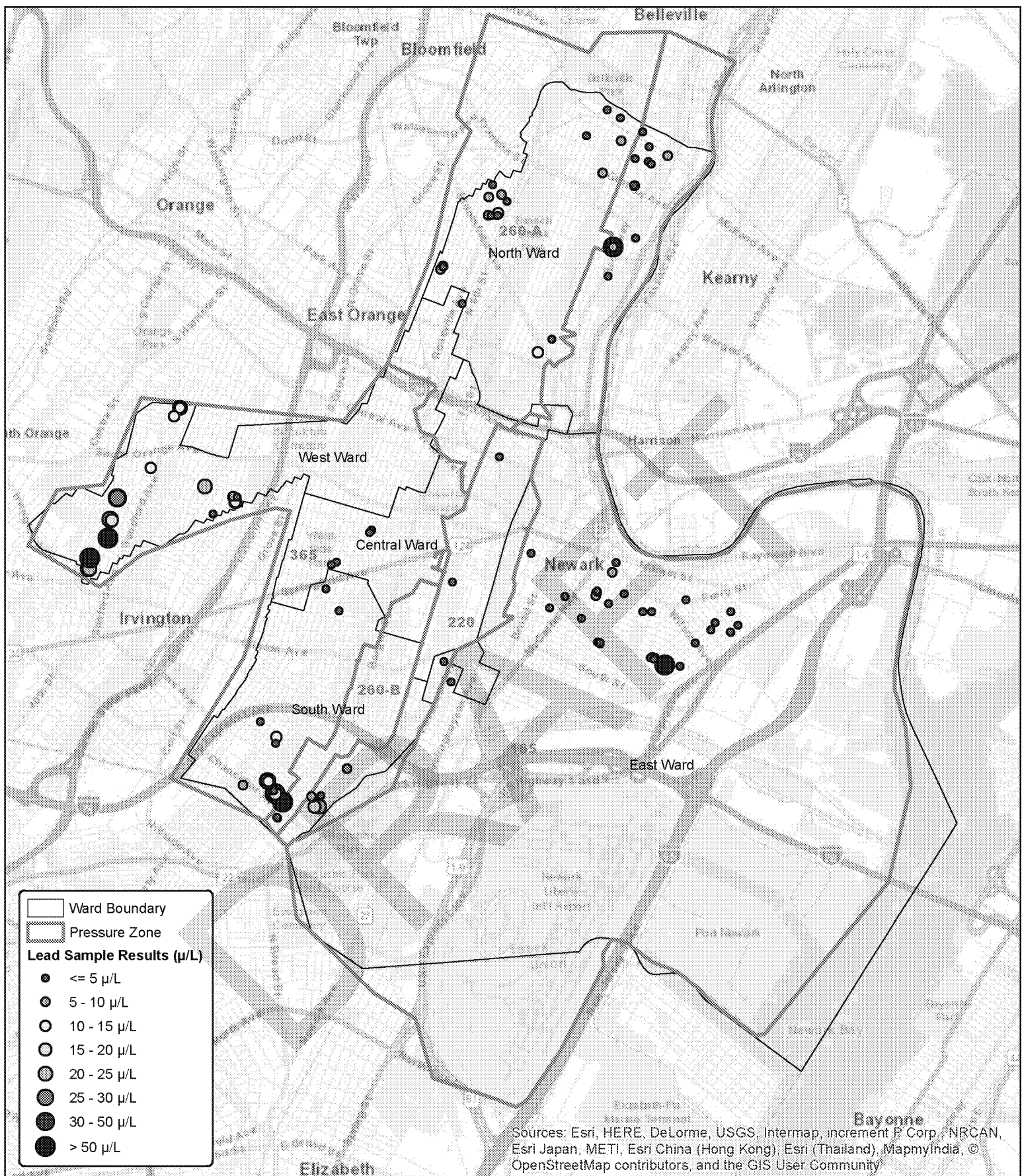
## Lead Level in the City of Newark

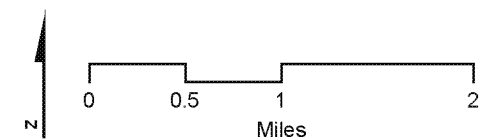
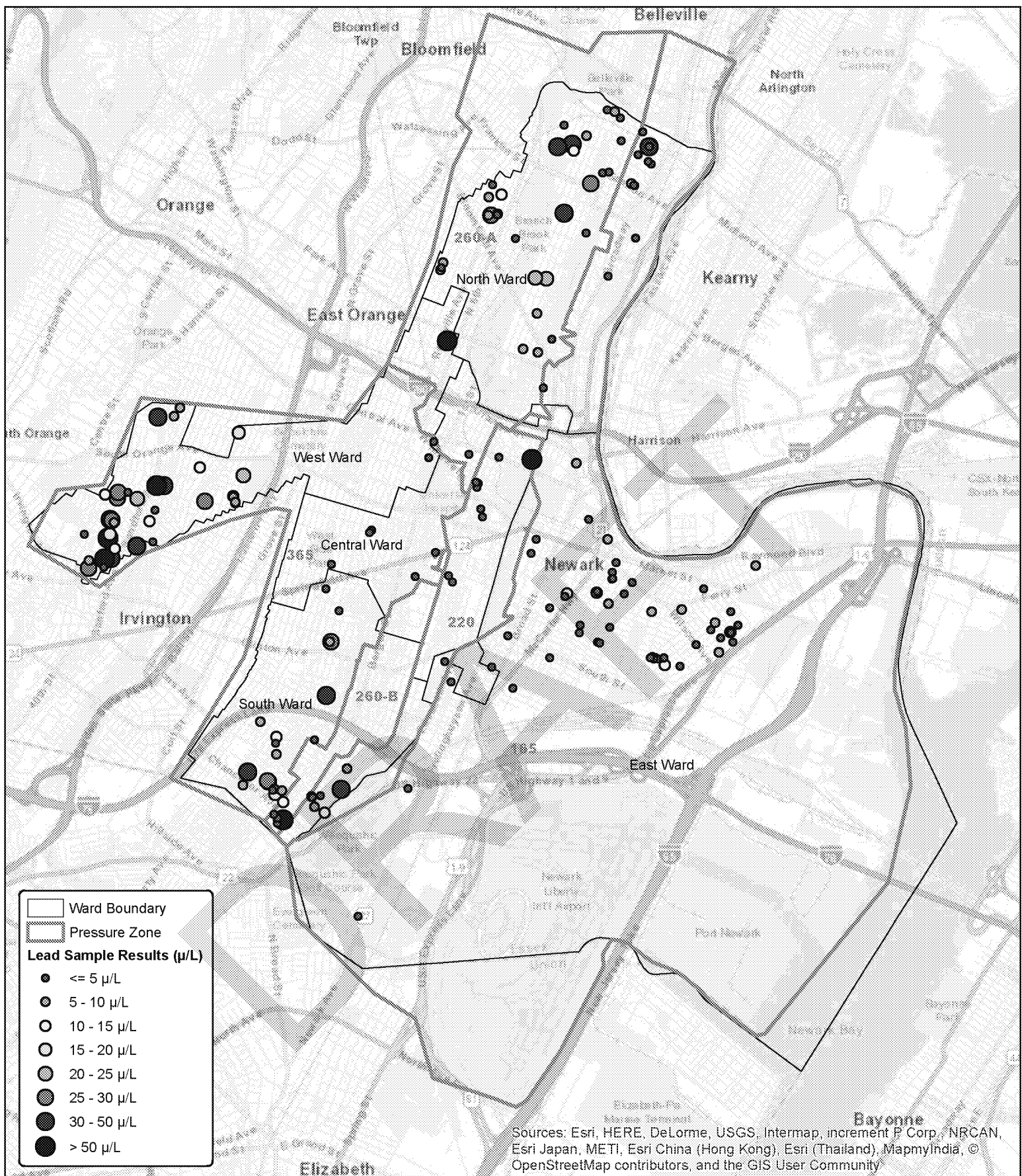
Data Collected: 2012

Figure 1-8







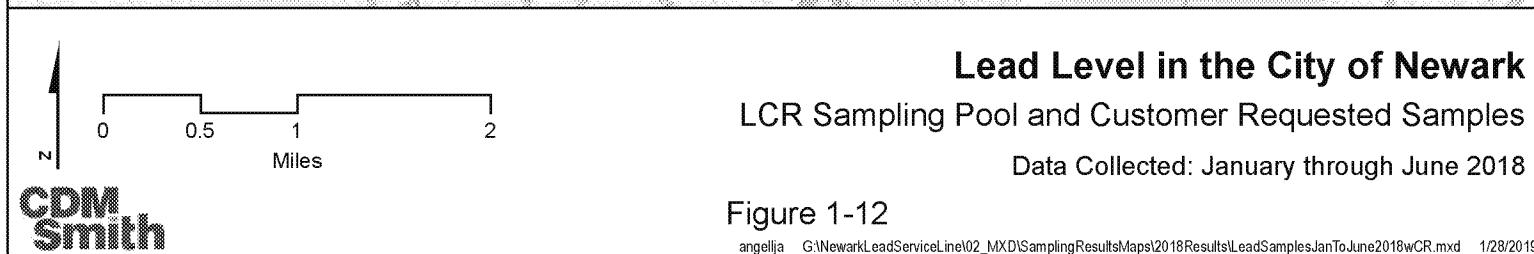
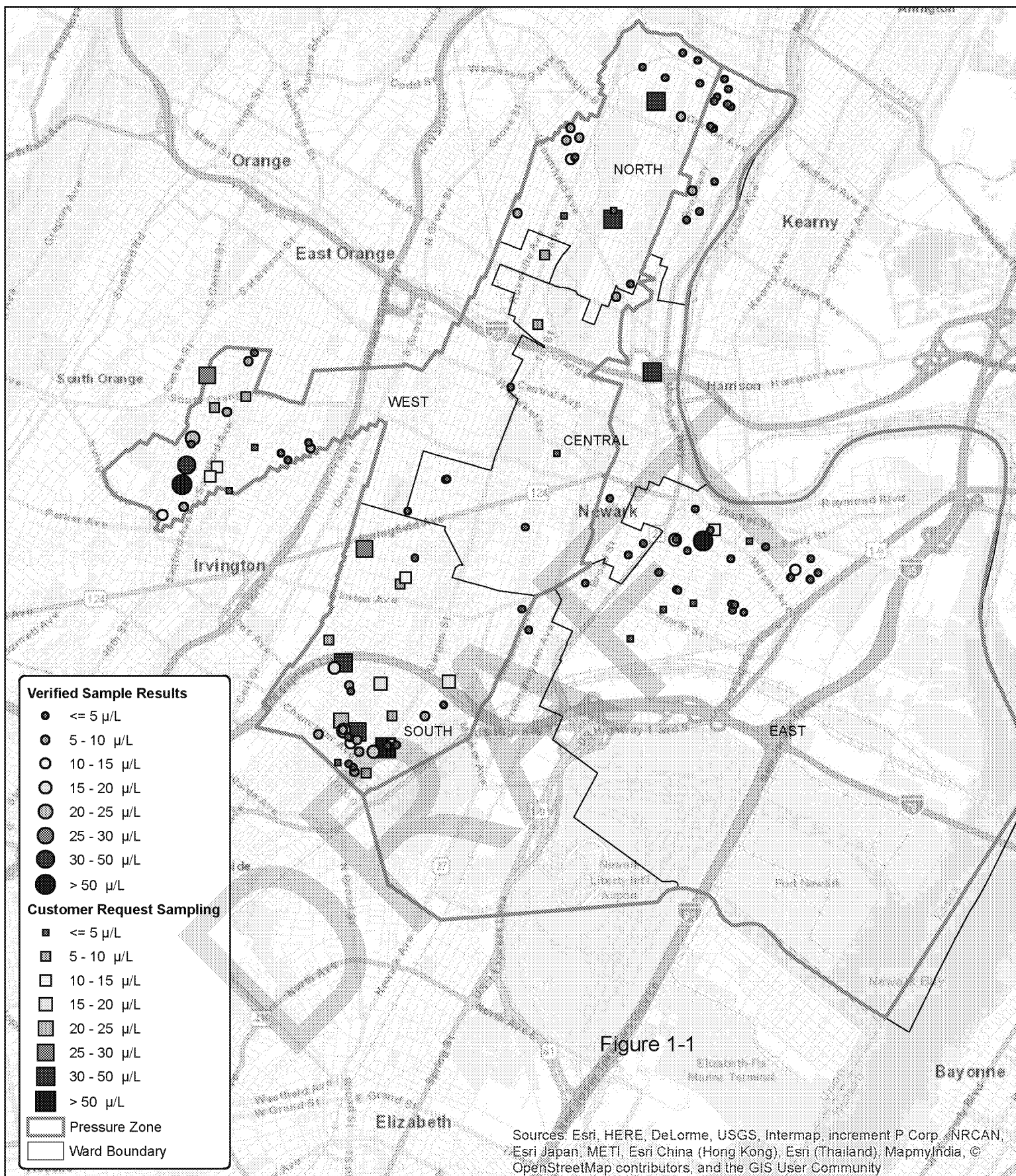


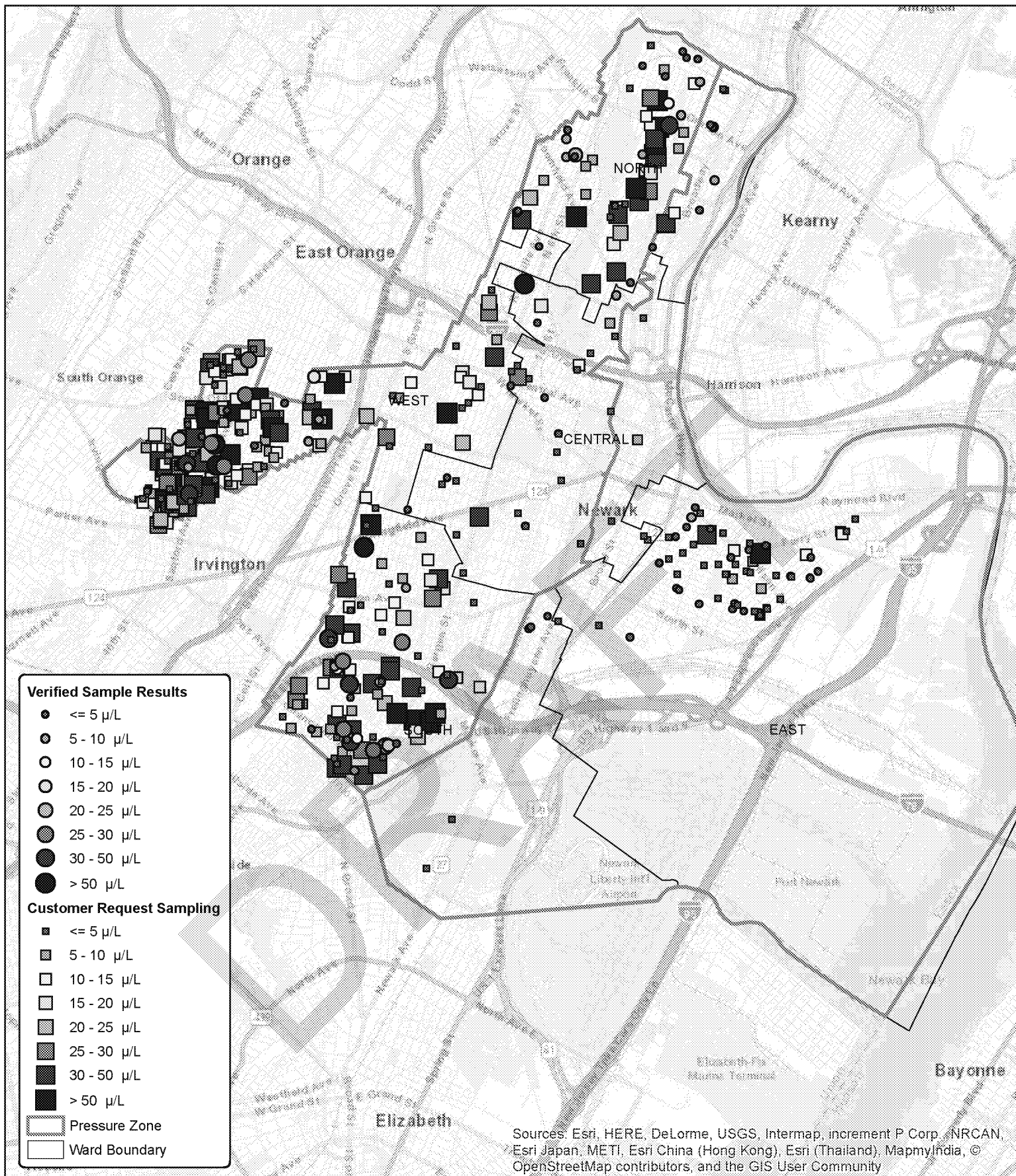
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## Lead Level in the City of Newark

Data Collected: July - December 2017

Figure 1-11

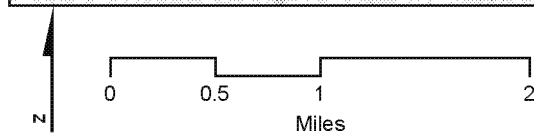
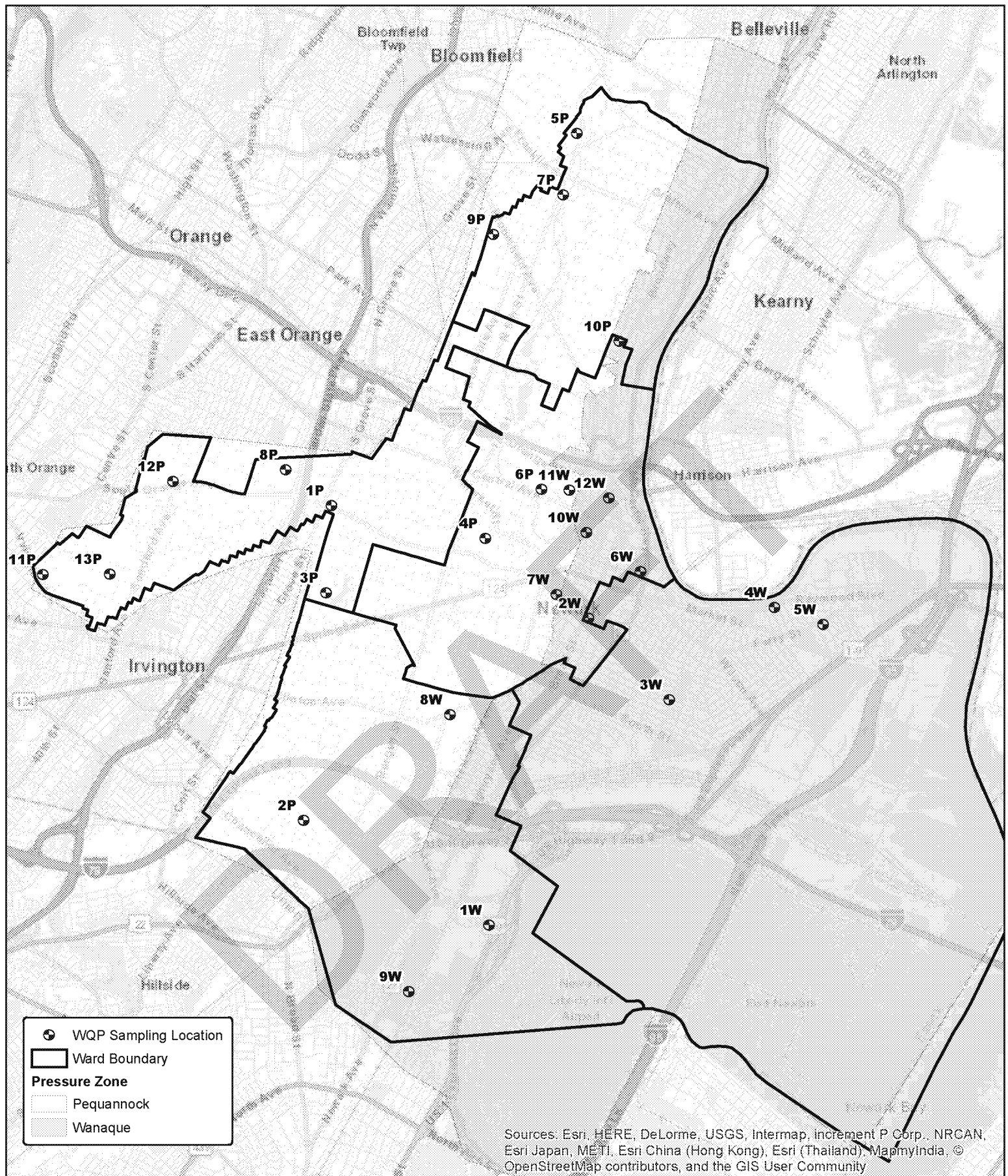




**Lead Level in the City of Newark**  
 LCR Sampling Pool and Customer Requested Samples  
 Data Collected: July through December 2018

Figure 1-13





## Newark WQP Sampling Locations

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## Section 2

### Lead Frequency Distribution

A frequency distribution analysis was conducted using multiple rounds of compliance sampling data for both the Pequannock and Wanaque service areas. The analysis was conducted for each service area separately as the service areas receive different CCT as described in Section 1. Although regulatory compliance is based on the City of Newark as a whole, the corrosion control chemistry of the two service areas differ. Therefore, the systems were evaluated separately to understand the cause of the high lead levels found in homes within the City of Newark with lead service lines and/or plumbing components containing lead.

Frequency distributions can provide insight as to whether changes in lead levels may be the result of CCT, sampling variability, or a combination of the two (Burlingame, 2004). Frequency distributions can assist in establishing the cause of a change in the 90th percentile value and AL exceedance. The frequency distribution presented in this Section provides an analysis of the lead sampling results collected since 1992. The data were sorted into several “bins” and percentile categories by lead concentration. The three “bins” that provide the best indication of whether or not CCT has been optimized are: (1) percent less than or equal to 5 µg/L, (2) 50th (median) percentile (µg/L), and (3) percent greater than 15 µg/L and less than or equal to 25 µg/L. Overall trends are also revealed by the frequency distribution data.

This section presents an updated frequency distribution to the October 2018 report and includes the second half of 2018 sampling for the Pequannock and Wanaque service areas.

#### 2.1 Lead Frequency Distribution – Pequannock Service Area

For the Pequannock service area, the frequency distribution analysis was conducted for compliance sampling data collected in 1992, 1998, 2003, 2006, 2012, 2015, the two sampling periods in 2017, and the two sampling periods in 2018. Lead sampling rounds were also conducted by the City of Newark in 2002 and 2009; however, not enough samples were available in the Pequannock Gradient for a statistical analysis in those two years likely based on customer responsiveness.

**Figure 2-1** provides an overview of the lead sampling compliance data from the ten (10) sampling events for the Pequannock service area for the different “bins” from less than 5 µg/L to greater than 50 µg/L. **Table 2-1** provides a summary of some statistical parameters based on the lead sampling compliance data, and **Table 2-2** provides an interpretation of the findings of the frequency distribution analysis for the Pequannock service area.

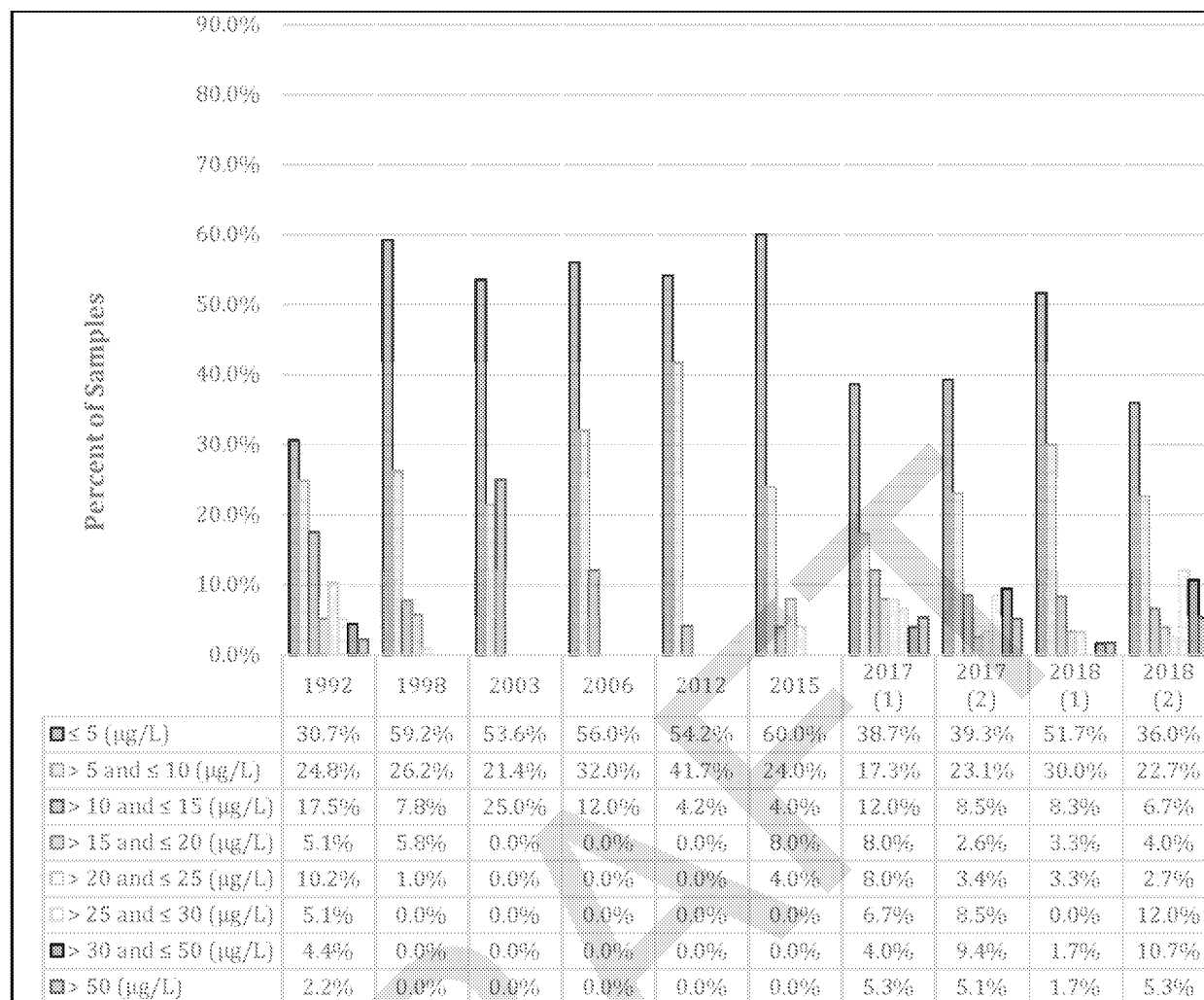


Figure 2-1 – Pequannock Service Area – Lead Sampling Data Percentage Frequency Distribution

Table 2-1 – Summary of Statistical Parameters for Pequannock Lead Sampling Data

Parameter	1992	1998	2003	2006	2012	2015	2017 (1)	2017 (2)	2018 (1)	2018 (2)
50th Percentile	8.5	4.0	4.8	4.1	5.0	0.0	7.4	7.8	0.0	7.6
75th Percentile	16.3	7.4	10.0	7.4	7.3	8.0	17.8	21.2	8.2	27.7
90th Percentile	26.8	12.3	12.2	9.5	9.7	15.8	29.8	36.0	14.8	39.5
Number of Samples (n)	137	103	28	25	24	25	75	117	60	75
Number of Samples >15 (n)	37	7	0	0	0	3	24	34	6	26
Percent > 15 and ≤ 25 (µg/L)	15.3%	6.8%	0.0%	0.0%	0.0%	12.0%	16.0%	6.0%	6.7%	6.7%
Maximum (µg/L)	60.4	23.0	14.2	11.5	14.0	25.0	137.0	77.7	52.6	72.2



**Table 2-2 – Pequannock Service Area Frequency Distribution Analysis**

<b>Data Category/Bin</b>	<b>What does it tell us?</b>	<b>Newark Pequannock Pb Results</b>
Overall frequency distribution	Gives a comprehensive picture of sampling results and allows for comparisons over different periods of time.	The Pequannock WTP implemented sodium silicate chemical addition for CCT in 1997. The lead results from 1998 through 2012 reflect effective control of lead release. However, starting in 2015, lead levels returned to and, in some cases, exceeded 1992 levels. This points to a significant change in system behavior around 2015.
Less than or equal to 5 µg/L	Typically, optimization of a corrosion control treatment is signified by an increased percentage of values that are less than 5 µg/L. When water is treated to be less corrosive, or chemistry is modified to create a stable and insoluble lead compound, overall lead levels will decrease, thereby increasing the percentage of samples with the lowest lead concentrations.	The percentage of samples less than or equal to 5 µg/L increased after CCT was implemented (1997). However, this category only saw 60% of the samples at best, compared to optimized systems which typically see well above 80% of samples less than 5 µg/L. In 2017 and the second half of 2018, the number of samples less than 5 µg/L decreased significantly from 50-60% to slightly less than 40%.
50th percentile (µg/L)	The nature of the 90th percentile Action Level is such that it only takes a few samples to greatly affect the outcome of a monitoring period. One seemingly benign deviation in the sampling protocol can greatly skew the 90th percentile value. The 50th percentile is much more resilient and, as such, is a good indicator of the relative effectiveness of a CCT.	The 50 <sup>th</sup> percentile value decreased from 1992 levels by about half after CCT was implemented in 1997. However, the 50 <sup>th</sup> percentile nearly doubled in 2017 and the second half of 2018.
Greater than 15 µg/L and less than or equal to 25 µg/L	A small deviation within the 15 to 25 ppb range of samples above could put a system out of compliance. By improving the CCT, a system can provide a greater buffer between the 90th percentile values and the AL of 15 ppb, so as to lessen the effects of an unrepresentative sample.	Prior to implementation of CCT (1992), a significant percentage (15%) of the samples were in this range. After many years of no results being in this range, an uptick in results between 15 and 25 ppb began in 2015, continuing to the first half of 2017; and were still elevated thereafter but slightly less than between 2015 and the first half of 2017. This may be indicative that the most significant impact to the pipe scales may have peaked by early 2017, but this cannot be confirmed.

## 2.2 Lead Frequency Distribution – Wanaque Service Area

A frequency distribution analysis was conducted for compliance sampling data collected in 1992, 2002, 2009, 2012, 2015, the two sampling periods in 2017, and the two sampling periods in 2018 for the Wanaque service area. Lead sampling rounds were also conducted by the City of Newark in 1998 and 2003; however, not enough samples were available in the Wanaque Gradient for a statistical analysis in those two years likely based on customer responsiveness.

**Figure 2-2** provides an overview of the lead sampling compliance data from the ten (10) sampling events for the Wanaque service area for the different “bins” from less than 5 µg/L to greater than 50 µg/L. **Table 2-3** provides a summary of some statistical parameters based on the lead sampling compliance data, and **Table 2-4** provides an interpretation of the findings of the frequency distribution analysis for the Wanaque service area.



**Figure 2-2 – Wanaque Service Area – Lead Sampling Data Percentage Frequency Distribution**

**Table 2-3 – Summary of Statistical Parameters for Wanaque Lead Sampling Data**

Parameter	1992	2002	2003	2009	2012	2015	2017 (1)	2017 (2)	2018 (1)	2018 (2)
50th Percentile	6.6	4.6	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
75th Percentile	14.2	9.0	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90th Percentile	25.7	11.2	8.4	0.0	6.2	2.0	7.4	8.7	7.0	4.1
Number of Samples (n)	93	114	29	26	27	27	46	67	49	31
Number of Samples >15 (n)	22	0	0	1	1	1	3	1	2	0
Percent > 15 and ≤ 25 (µg/L)	12.9%	0.0%	0.0%	3.8%	3.7%	0.0%	0.0%	0.0%	2.3%	0.0%
Maximum (µg/L)	49.4	14.9	12.3	24.6	19.0	37.0	84.0	46.1	182.0	9.3

**Table 2-4 – Wanaque Service Area Frequency Distribution Analysis**

Data Category/Bin	What does it tell us?	Newark Wanaque Pb Results
Overall frequency distribution	Gives a comprehensive picture of sampling results and allows for comparisons over different periods of time.	The Wanaque WTP implemented zinc orthophosphate chemical addition for CCT treatment in the mid 1990s. Between 1992 and 2018, lead sampling results for the Wanaque service area shifted in multiple “bins” (ranges). The 1992 sampling was prior to the CCT treatment improvements. These results point to CCT effectiveness as the cause of a significant decrease in action level beginning in the early 2000s and a shift in the percentage of results into lower bins.
Less than or equal to 5 µg/L	Typically, optimization of a corrosion control treatment is signified by an increased percentage of values that are less than 5 µg/L. When water is treated to be less corrosive, or chemistry is modified to create a stable and insoluble lead compound, overall lead levels will decrease, thereby increasing the percentage of samples with the lowest lead concentrations.	Between 1992 and 2018, there was a large increase in % of samples in this category. Where 1992 saw 32% of samples in this category, 2017 and 2018 sampling saw an increase to an average of 84% between the four sampling pools for lead results less than or equal to 5 ppb. This can again be tied to CCT treatment of zinc orthophosphate. Typically, optimized systems have a majority of sample results (>80%) in the category of <5 ppb.

Data Category/Bin	What does it tell us?	Newark Wanaque_Pb Results
50th percentile ( $\mu\text{g/L}$ )	The nature of the 90th percentile Action Level is such that it only takes a few samples to greatly affect the outcome of a monitoring period. One seemingly benign deviation in the sampling protocol can greatly skew the 90th percentile value. The 50th percentile is much more resilient and, as such, is a good indicator of the relative effectiveness of a CCT.	The 50 <sup>th</sup> percentile value decreased from 6.6 in 1992 to zero (0) in 2009, and has remained as such ever since indicating effectiveness of the zinc orthophosphate CCT treatment.
Greater than 15 $\mu\text{g/L}$ and less than or equal to 25 $\mu\text{g/L}$	A small deviation within the 15 to 25 $\mu\text{g/L}$ range could put a system out of compliance. By improving the CCT, a system can provide a greater buffer between the 90th percentile values and the AL of 15 $\mu\text{g/L}$ , so as to lessen the effects of an unrepresentative sample.	There was a large decrease in the number of results in this category after the initial sampling round in 1992, which was prior to implementation of CCT. In 2009, 2012 and first half of 2018, there was a slight increase in this category, which could indicate sampling variability but not definitively. Overall, occurrences of lead levels above the action level decreased significantly indicating the effectiveness of the CCT treatment.

## 2.3 Service Area Comparison

When separating the LCR compliance sampling data for the Pequannock and Wanaque Gradients, it is clear from the results of the individual lead frequency distribution analyses that a large majority of the lead exceedances have occurred in the Pequannock service area. The frequency of lead exceedances in Pequannock alone has triggered the lead AL exceedances for the City of Newark since the first half of 2017. If the Pequannock and Wanaque Gradients were regulated independently, the Wanaque service area would have been in compliance with the Lead and Copper Rule from 2002 to present with 90<sup>th</sup> percentile values ranging from 0.0 to 11.2  $\mu\text{g/L}$  over that period. Over that same period, the Pequannock 90<sup>th</sup> percentile values ranged from 9.5 to 39.5  $\mu\text{g/L}$ . In the most recent sampling round, the second half of 2018, the Pequannock 90<sup>th</sup> percentile based on the verified LCR sampling pool was 39.5  $\mu\text{g/L}$  and the Wanaque 90<sup>th</sup> percentile based on the verified LCR sampling pool was 4.12  $\mu\text{g/L}$ .

If the customer requested samples are included in a 90<sup>th</sup> percentile calculation with the LCR compliance samples, the lead results in the first and second half of 2018 are higher but still indicate the major difference between the Pequannock and Wanaque Gradients. The Pequannock 90<sup>th</sup> percentile calculation for all samples (LCR compliance and customer requests) is 23.62  $\mu\text{g/L}$  for the first half of 2018 and 46.74  $\mu\text{g/L}$  for the second half of 2018. The Wanaque 90<sup>th</sup> percentile calculation for all samples (LCR compliance and customer requests) is 8.68  $\mu\text{g/L}$  for the first half of 2018 and 9.61  $\mu\text{g/L}$  for the second half of 2018. This calculation includes homes where the materials are not verified and are, therefore, not included in the official LCR compliance

calculation. A 90th percentile calculation with customer requests is not a compliance requirement and is presented herein only to show the 90th percentile with an expanded pool of data.

The historic LCR compliance sampling data, as well as the data recently collected as part of this study, show that the current CCT for the Wanaque service area is able to consistently reduce lead levels in the drinking water to below the lead AL.

Due to the determination that the Pequannock system is triggering the lead AL exceedances for the City of Newark, the study on the Pequannock system was prioritized and submitted in draft form in October 2018 to the NJDEP. The draft report evaluated the cause of the elevated lead levels and provided recommendations for reducing lead levels in the Pequannock system which are currently being implemented.

Since, as a whole, the entire City of Newark is not currently meeting the lead AL due to the Pequannock/Wanaque combined reporting, a more detailed report was requested by NJDEP providing further analysis on the Wanaque Gradient, including sequential sampling and pipe scale analyses. If necessary, recommendations for optimization of the CCT in the Wanaque Gradient and recommendations to reduce the public's exposure to lead in drinking water in the Wanaque service area will be provided in Section 6 once the analyses are complete.

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## Section 3

### Water Quality

Historic water quality data was obtained from NJDEP Drinking Water Watch (as of 01/22/2019) and is summarized in this section. Data from PWSID NJ0714001 (Newark Water Department) and PSWID NJ1613001 (NJDWSC – Wanaque North) were used. Data were also obtained from Newark’s WQP sampling locations in the Wanaque Gradient between July 2016 and December 2018.

The following subsections review the water quality of the Wanaque Gradient’s point of entry (POE) and within Newark’s distribution system.

#### 3.1 Wanaque Gradient Point of Entry (POE) Water Quality Data

This section pending additional data analysis and confirmation.

#### 3.2 Wanaque Gradient Distribution System Water Quality Data

As mentioned in Section 1, Newark has been monitoring WQPs since July 2016 on a regular basis at several sampling locations. This includes points of entry into the distribution system (Sample House (PWTP), 1294 McBride Avenue in Little Falls, Montclair Re-chlorination Station and the Belleville Reservoir Complex) on a bi-weekly basis and 25 sampling locations in the distribution system on a quarterly basis. The sampling locations for monitoring Newark’s distribution system WQPs are shown in **Figure 1-14**. According to the list, there are 13 WQP sampling locations in the Pequannock service area (labeled with “P”) and 12 WQP sampling locations in the Wanaque service area (labeled with “W”). However, based on the addresses provided for these sample locations, it appears that the following WQPs may be labeled incorrectly. The sample locations are being further investigated to confirm which system they are currently monitoring.

- 7W – Labeled as Wanaque but in the Pequannock service area
- 8W – Labeled as Wanaque but in the Pequannock service area
- 11W – Labeled as Wanaque but in the Pequannock service area
- 10P – Labeled as Pequannock but in the Wanaque service area

The water quality data for the 25 WQP sampling locations in the distribution system was only provided until the end of October 2018, as those locations are reported on a quarterly basis.

**Table 3-1** summarizes the min, avg and max values of pH, alkalinity, orthophosphate and silica at the WQP distribution sampling locations in the Pequannock and Wanaque Gradients. Sampling locations 7W, 8W and 11W are included with Pequannock’s data and sampling location 10P is included with Wanaque data based on their physical locations in the system.

**Table 3-1 – Pequannock and Wanaque Gradient WQP Distribution System Water Quality  
(July 2016 – October 2018)**

Parameter	Pequannock			Wanaque		
	Min	Avg	Max	Min	Avg	Max
pH	6.69	7.46	8.73	6.86	7.52	8.30
Alkalinity (mg/L as CaCO <sub>3</sub> )	21.40	30.57	59.3	21.30	33.73	51.60
Orthophosphate (mg/L as PO <sub>4</sub> )	ND	0.09	1.39	ND	0.52	2.37
Silica (mg/L as Silica)	3.70	6.18	8.80	1.24	4.93	8.19

As can be seen in **Table 3-1**, there are some similarities and some distinct differences between the water quality in the Pequannock Gradient and the Wanaque Gradient. Some observations include:

- The pH values are very similar between the Pequannock and Wanaque Gradients; however, the Wanaque Gradient appears to have a more consistent pH than the Pequannock Gradient.
- Average alkalinity in the Wanaque Gradient is slightly higher at 34 mg/L as CaCO<sub>3</sub> than the Pequannock Gradient at 31 mg/L as CaCO<sub>3</sub>; however, the seasonal variations are similar.
- Orthophosphate residual is significantly higher in the Wanaque Gradient than the Pequannock Gradient, although lower on average than at the target dose of 1.8 mg/L to 2.2 mg/L as PO<sub>4</sub> at the POE leaving the Belleville Reservoir Complex. The Pequannock Gradient occasionally gets water with orthophosphate from one of its interconnections with PVWC or Jersey City which may explain the PO<sub>4</sub> concentrations that appear in limited samples.
- The silica concentration is significantly higher for the Pequannock Gradient on average than the Wanaque Gradient, although the maximum values are similar.

### 3.2.1 Wanaque and Pequannock Mixing

There are two known ways that water can flow from the Pequannock Gradient to the Wanaque Gradient. Specifically, there are forty-seven (47) division gate valves and eight (8) pressure regulating valves within the Newark distribution system that can send water from Pequannock to Wanaque on an as needed basis. These valves are closed under normal operating conditions and are intended to separate Wanaque and Pequannock Gradients. Division gates are operated manually whereas pressure regulating valves open and close automatically based on a set pressure differential between the two gradients. These valves provide added resiliency to Newark's water distribution system as they can divert water to areas in need on a temporary basis, such as a water main break, low flow condition, or emergency such as a fire. Since the Wanaque Gradient is lower (165 feet) compared with the Pequannock Gradient (over 200 feet), water will typically move from the higher Pequannock Gradient to the lower Wanaque Gradient and not from Wanaque to Pequannock unless there were to be a significant drop in pressure in



the Pequannock Gradient. The City is in the process of investigating and evaluating the pressure reducing valves and division gates to determine if there are any leaking or malfunctioning valves within the system. The assessment of these valves will be provided along with Newark's final report on Wanaque's CCT.

Based on a review of the WQP data, it appears that there may be some areas in Wanaque that may be supplemented with Pequannock water. These areas are evidenced by the low levels of orthophosphate as seen in certain Wanaque sample results. Homes in these suspect locations were targeted for sequential sampling. Results of the sequential sampling in these areas are further discussed in Section 4 of this report. **Tables 3-2 and 3-3** provide the minimum, average and maximum values for pH, alkalinity, orthophosphate and silica at each Pequannock and Wanaque WQP sampling location from July 2016 to October 2018. The data was used to identify potential locations where the water supply in the Wanaque Gradient may be supplemented by the water supply in the Pequannock Gradient. The silica, orthophosphate and alkalinity values for each WQP sampling location were compared with the ranges shown in **Table 3-1** for each gradient, assumptions were made as to where supplementation of the water supplies may be occurring.

In **Table 3-3**, the highlighted orange rows represent the sampling locations in the Wanaque Gradient that appear to be "Likely Supplemented by Pequannock" water and the highlighted yellow rows represent the sampling locations that may be "Potentially Supplemented by Pequannock" water in the distribution system. The following criteria was used to determine the two areas:

**Likely Supplemented by Pequannock:**

- Average silica concentrations greater than 5.5 mg/L as silica
- Average orthophosphate levels less than 0.4 mg/L as PO<sub>4</sub>

**Potentially Supplemented by Pequannock:**

- Average silica concentrations slightly above the Wanaque average silica concentration
- Average orthophosphate levels slightly below the Wanaque average orthophosphate level

Sampling locations 2W, 10P, 10W and 12W (orange highlighted rows) are assumed to be "Likely Supplemented by Pequannock" water. This was determined by observing that the individual average orthophosphate levels were below the orthophosphate level of 0.40 mg/L as PO<sub>4</sub> over the same period of record. At the same time, these locations have an average silica concentration greater than 5.5 mg/L which is higher than the typical silica concentration at the Belleville Reservoir Complex. These sampling locations have fluctuating levels of orthophosphate and silica, indicating likely intermittent supplementing of the Wanaque Gradient with Pequannock water.

Table 3-2 - Pequannock WQP Sampling Locations Summary (July 2016 - October 2018)

Pequannock													
Sample ID	WQP Sampling Locations	pH			Alkalinity (mg/L as CaCO <sub>3</sub> )			Orthophosphate (PO <sub>4</sub> )			Silica (mg/L as Silica)		
		min	average	max	min	average	max	min	average	max	min	average	max
TH	Sample House, PWTP	6.35	7.11	7.94	14.30	25.67	42.05	0.00	0.03	0.33	4.88	7.95	12.00
VR	Montclair Rechlorination Stn. 782 Valley Road	6.29	7.25	7.82	20.50	29.75	43.25	0.00	0.01	0.30	3.78	6.03	9.48
1P	Senior Home, 545 Orange Street	7.15	7.45	7.82	23.60	29.49	37.20	Null			4.29	6.66	8.80
2P	Beth Israel Hospital, 201 Lyons Avenue	6.76	7.56	8.15	23.00	29.66	37.70	Null			4.06	6.31	7.60
3P	South 17th School, 619 South 17th Street	6.69	7.37	7.86	23.30	29.50	36.40	Null			4.23	6.53	8.03
4P	Univeristy Hospital, 16 Bergen Street	6.85	7.33	7.65	24.00	29.44	35.00	Null			4.05	6.14	7.75
5P	Stephen Crane Village, 4 Steven Crane Plaza	6.91	7.61	8.46	23.10	32.96	40.00	Null			4.11	5.93	8.05
6P	City of Newark, 239 Central Avenue	6.89	7.41	7.72	23.10	30.54	42.40	Null			4.20	6.34	8.18
7P	Senior House 801 North 6th Street	7.05	7.38	7.98	21.40	29.49	34.00	Null			4.37	6.42	8.34
7W	Newark Health Service, 94 William Street	7.05	7.43	7.84	24.30	31.41	37.00	0.00	0.09	0.62	3.95	5.88	7.58
8P	Bradley Courts, 46N Munn Avenue	6.89	7.54	7.86	21.40	29.44	35.00	Null			4.07	6.14	7.90
8W	Firehouse, 360 Clinton Avenue	6.88	7.48	7.77	24.50	31.88	36.70	0.00	0.15	1.39	3.70	5.89	7.98
9P	Columbus Hospital 495N 13th Street	6.87	7.30	7.72	22.00	29.67	35.70	Null			4.01	6.48	8.09
11P	Ivy Hill Liquors 521 Ivy Hill Plaza	7.01	7.65	8.73	22.70	30.89	36.70	Null			4.54	6.02	8.03
11W	Senior Citizen Home, 9 Summit Street	7.11	7.42	7.92	23.30	30.74	38.40	0.00	0.04	0.24	4.45	5.96	7.72
12P	Sanford Avenue Pharmacy, 1041 South Orange Avenue	6.72	7.42	7.89	21.50	32.39	59.30	Null			4.12	6.09	8.00
13P	Sub City, 81 Mount Vernon Place	6.75	7.50	8.37	23.00	31.11	41.30	Null			4.01	5.97	8.01

Table 3-3 - Wanaque WQP Sampling Locations Summary (July 2016 - October 2018)

Wanaque													
Sample ID	WQP Sampling Locations	pH			Alkalinity (mg/L as CaCO <sub>3</sub> )			Orthophosphate (PO <sub>4</sub> )			Silica (mg/L as Silica)		
		min	average	max	min	average	max	min	average	max	min	average	max
1W	Holiday Inn, 450 Route 1 & 9 South	7.34	7.81	8.30	31.80	40.38	50.30	0.11	1.41	2.37	1.24	2.66	5.29
2W	Newark City Hall, 930 Broad Street	7.08	7.42	7.67	23.00	32.41	38.00	0.00	0.09	0.72	4.44	5.72	7.52
3W	Glamour's Salon, 251 Oliver Street	7.02	7.53	7.97	25.70	33.63	38.20	0.29	0.67	1.34	3.14	4.61	6.47
4W	River Bank Auto Repairs, 638 Raymond Blvd	6.96	7.48	7.88	26.50	33.33	40.40	0.31	0.46	0.64	3.57	4.90	6.55
5W	Hawkins School, 9 Hawkins Street	6.90	7.43	7.95	25.30	32.95	38.20	0.00	0.40	0.67	3.50	4.75	6.91
6W	Seton Hall Law School, 1109 Raymond Blvd	6.99	7.59	8.13	27.00	32.34	38.20	0.00	0.45	0.70	3.19	5.01	6.22
9W	Associated Humane Society, 124 Evergreen Avenue	7.09	7.60	8.20	21.30	40.42	51.60	0.00	0.76	1.47	1.37	3.26	6.41
10P	Broadway House, 298 Broadway	7.15	7.38	7.88	21.80	29.17	35.00	Null			4.56	6.58	8.19
10W	Rutgers University, 190 Univeristy Avenue	6.86	7.41	7.89	23.60	30.92	38.20	0.00	0.33	2.02	4.50	6.08	7.77
12W	Newark Library, 5 Washington Avenue	7.15	7.52	7.86	24.00	31.77	38.20	0.00	0.12	0.34	4.35	5.70	6.83

**Legend**

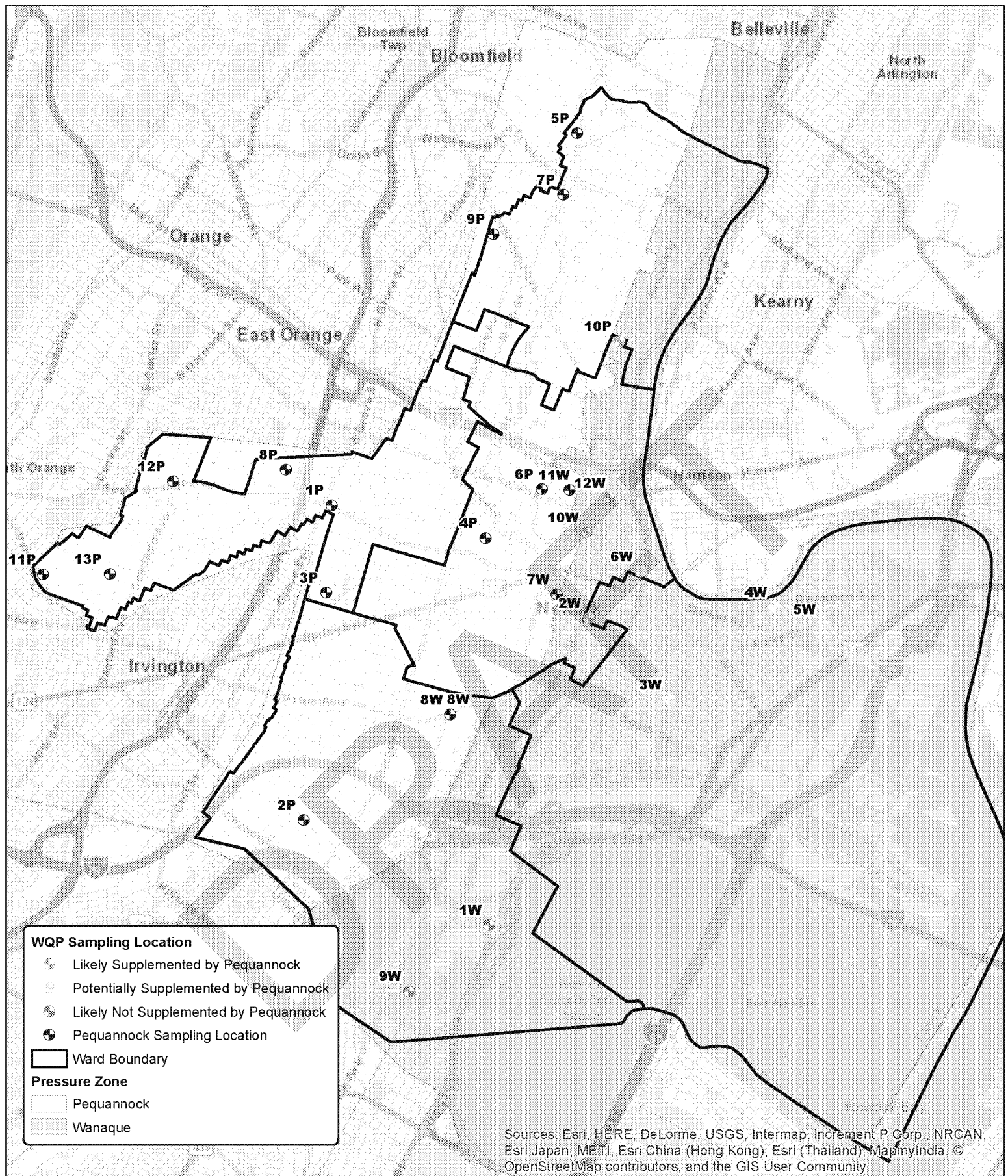
Likely Supplemented by Pequannock

Potentially Supplemented by Pequannock

Sampling locations 3W, 4W, 5W and 6W (yellow highlighted rows) may be “Potentially Supplemented by Pequannock” water on occasion. This was determined by observing that the average orthophosphate levels for these sample locations in **Table 3-3** are below the average orthophosphate for other WQP sample locations in Wanaque and the average silica concentration is below the average silica concentration for other sample locations in Wanaque and above the average level seen in the Belleville Reservoir Complex. The WQP sampling locations are shown in **Figure 3-1** indicating which are “likely” or “potentially” supplemented by Pequannock Gradient water.

Based on the lead levels in customer taps as presented in Section 2, the water quality in Wanaque Gradient does not appear to be affected enough to increase lead levels in the Wanaque Gradient to levels seen in the Pequannock Gradient or to levels triggering a lead AL exceedance. However, the low levels of orthophosphate seen in sections of the Wanaque Gradient should be addressed.

A zinc orthophosphate chemical feed system is currently under construction for the Pequannock Gradient and should be in service during the spring of 2019. In the interim, it is recommended that Newark tracks the WQPs at the sampling locations in the distribution system on a monthly basis to assist with further evaluation.



**Newark WQP Sampling Locations**  
Potential Influence from Pequannock  
on Wanaque Water Quality

### 3.3 Chloride-to-Sulfate Mass Ratio

Galvanic corrosion on lead solder joints on copper plumbing can be affected by chloride concentrations, as indicated by the chloride to sulfate mass ratio (CSMR). CSMR is calculated by dividing the average chloride concentration by the average sulfate concentration (Nguyen, Stone, Clark, & Edwards, 2010). The literature reports a “threshold” CSMR value of 0.5, above which galvanic corrosion of lead solder on copper piping can increase. The greatest concerns, however, are utilities with lead solder joints that change their water chemistry to increase CSMR from below 0.5 to above 0.5 as indicated in the Water Research Foundation (WRF) 4088 Study (Nguyen, Stone, Clark, & Edwards, 2010).

The researchers in the WRF study observed that in waters with CSMR equal to or less than 0.5, very low corrosion rates were observed. High chloride relative to sulfate, yielding CSMRs above 0.5, tended to increase galvanic corrosion of lead solder connected to copper pipe. They also observed, statistically, that as relative concentrations of chloride to sulfate increased in the water supply, the 90th percentile lead concentration generally increased. In their bench-scale experiments, waters with high CSMR were consistently more aggressive in increasing lead leaching from solder galvanically connected to copper.

Historic chloride and sulfate data are not available for Newark’s Wanaque Gradient distribution system. However, chloride and sulfate data from the same water source are available just downstream of the Wanaque WTP. Chloride and sulfate concentrations are not expected to change substantially throughout a distribution system, so they would be expected to be similar within Newark’s Wanaque Gradient. Based on an average chloride concentration of 46.0 mg/L and an average sulfate concentration of 14.2 mg/L, Wanaque’s average CSMR is 3.2. Although Wanaque’s CSMR is above the 0.5 threshold, there are many systems that operate with similar or higher CSMRs that do not have high lead levels or AL exceedances. The likely reason for this is that much of the solder exposed to the water may have been released at very low rates over decades. The WRF research focused on simulating release of lead from solder that was abruptly subjected to high CSMR water. This is corroborated by full-scale experience where the CSMR changed abruptly due to a process or water quality change (e.g., systems changing from alum to PACl or alum to ferric chloride). In these cases, the “baseline” condition was a relatively low CSMR (however, often times greater than 0.5), and the operation change caused a sudden increase in CSMR, which contributed to lead release and spikes in tap water sampling results (Nguyen, Stone, Clark, & Edwards, 2010).

Data were obtained from 1993 to 2018 from NJDEP WaterWatch for PSWID NJ1613001, under TP003006, which represents the chloride and sulfate concentrations for a system downstream of the Wanaque WTP. The only data available for chloride and sulfate is one data point per year which is not sufficient to make a determination on whether or not the CSMR is increasing.

Based on discussions with the plant operators, no major treatment changes have been made in the last 20+ years that would impact chloride and sulfate concentrations. Raw water data was not available at the time of this draft report. If sufficient raw water quality data can be obtained, additional analyses will be performed and included in an updated draft of this report.

Research and field experience indicate that orthophosphate can be effective in reducing lead release in conditions of galvanic corrosion, which is typically marked by a combination of low pH and high CSMR at the solder surface (Nguyen, Stone, Clark, & Edwards, 2010)). The Wanaque Gradient is already dosing zinc orthophosphate in the drinking water.

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## Section 4

# Sequential Sampling

The City of Newark conducted sequential sampling at seven locations in the Wanaque Gradient in December 2018 and January 2019. The purpose of this effort was to compare the Wanaque Gradient with the sequential sampling previously performed in the Pequannock Gradient and to evaluate potential sources of lead that may exist within the service line and premise plumbing from the service connection in the street to the drinking water tap in the house. Sequential sampling is an additional tool to assist in developing an understanding of the system as part of the CCT optimization. The sources of lead at the tap measured in sequential samples include lead service lines, lead-based materials contained in the premise piping (e.g., leaded solder, brass/bronze fittings, galvanized piping) and faucets.

### 4.1 Sequential Sampling Program Protocol

The sequential sampling program consisted of collecting the full volume of water between the kitchen faucet and the water main in small increments allowing for the isolation of water from various plumbing components, such as, but not limited to, fixtures, valves, pipe materials and meters. A memorandum dated September 10, 2018 by CDM Smith titled “Sequential Sampling Program Protocol for Tracking Lead in Drinking Water” provided the protocol for performing the sequential sampling.

In general, the sequential sampling process consisted of the following:

1. **Site Audit** - An initial visit to each home was conducted to document the cold-water piping, beginning at the faucet and traced back towards the water main in the street. This was used to calculate the volume in the water service line and determine the number and timing of samples needed for collection.
2. **Sample Collection and Analysis** - Sequential sampling is conducted after a stagnation period, between 6 to 12 hours, per the Lead and Copper Rule requirements. A 10-minute flush is conducted, without removing the faucet aerators, unless otherwise noted, prior to the stagnation period. Samples are taken at the kitchen sink in increments of 500 mL, or as determined by the site audit. A flushed sample is also taken at the end of the sequential program to test the water in the main. The faucet aerator was typically not removed for the flushing, with an exception described later in this section. The aerator was generally removed for sampling, depending on its accessibility. Samples were analyzed for the following information:
  - *pH (first sample, a middle sample, and flushed final sample measured in the field)*
  - *Temperature (first sample, a middle sample, and flushed final sample measured in the field)*

- *Free chlorine (first sample, a middle sample, and flushed final sample measured in the field)*
  - *Total Lead*
  - *Dissolved Lead*
  - *Total Copper*
  - *Silica Residual (SiO<sub>2</sub>) (first sample, a middle sample, and flushed final sample)*
  - *Orthophosphate (mg/L as P) (first sample, a middle sample, and flushed final sample)*
  - *Alkalinity (first sample, a middle sample, and flushed final sample)*
  - *Conductivity (first sample, a middle sample, and flushed final sample)*
3. **Data Evaluation** – Once the samples were analyzed, the profile was plotted with cumulative volume on the X-axis and lead results on the Y-axis. Specific plumbing components were located along the service volume axis and the plumbing components most contributing to high lead values were noted.
  4. **Monitoring** – If the CCT is modified, the sequential sampling program would be performed on a regular basis to ascertain the effectiveness of the new/modified CCT treatment.

## 4.2 Results of Sequential Sampling in the Wanaque Gradient

On December 14, 2018, CDM Smith coordinated sequential sampling for two residential locations in the Wanaque Gradient:

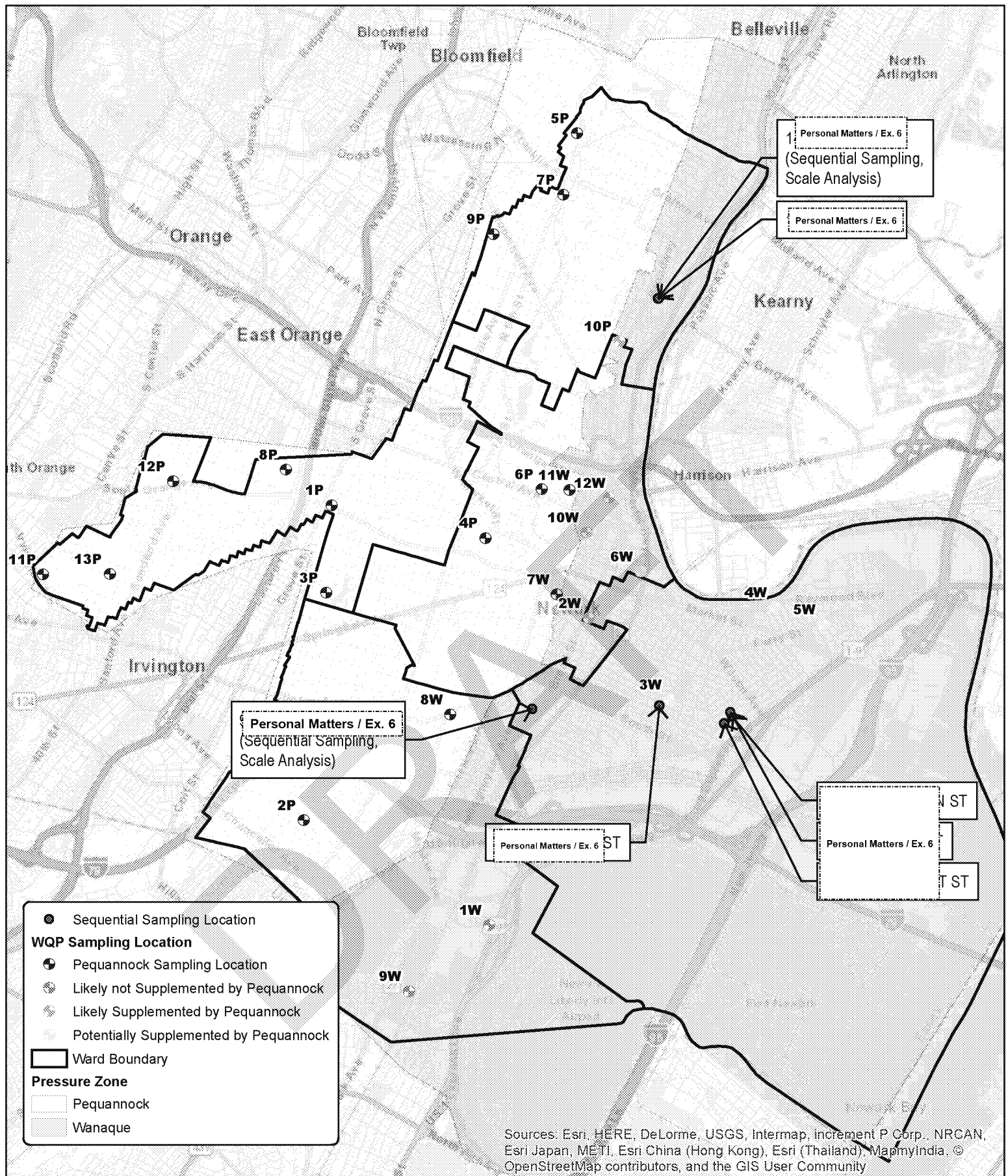
- **Personal Matters / Ex. 6** (East Ward)
- **Personal Matters / Ex. 6** (North Ward)

The locations of these homes are shown in **Figure 4-1**. Sequential sampling was performed as described in Section 4.1 with the faucet aerator left on for flushing, but removed for sampling. Once the sequential sampling was complete, the lead service lines were replaced and portions of the service lines were sent to the EPA for scale analysis. On January 19, 2019, sequential sampling was again performed at these two residential locations, approximately 1 month after the lead service line had been replaced with copper. In the second sampling at each home, the aerator was removed prior to flushing and kept off for the duration of the sampling.

Additionally, sequential sampling was performed on January 11, 14, and 21, 2019 at the following addresses:

- **Personal Matters / Ex. 6** (East Ward)
- **Personal Matters / Ex. 6** (East Ward)
- **Personal Matters / Ex. 6** (East Ward)





**Sequential Sampling and Scale Analysis Locations in Wanaque**

Figure 4-1

■ **Personal Matters / Ex. 6** (East Ward)

■ **Personal Matters / Ex. 6** (North Ward)

The locations of the sequential sampling sites are shown on **Figure 4-1**. The faucet aerator for these homes was left in place during flushing and removed during sampling when accessible.

The samples were analyzed for total and dissolved lead and the results are summarized in the subsections that follow. The background water quality was analyzed at the start of the testing (first sample or second sample), the middle of the testing (middle samples) and after a 10-minute flush (flushed sample).

For each location, total lead and soluble lead are plotted against the cumulative water volume in a profile to identify lead contributions from different plumbing materials. The difference between the total lead and soluble lead is insoluble or particulate lead. Particulate lead can be a result of scouring of deposits off the pipe wall disturbing the scale layers that have formed over time or from particulates collecting in the aerator or fixtures. Soluble lead is dissolved lead that has leached from the piping into the water. For each home's profile, the plumbing fixtures and materials are shown above the graph for correlation to the samples.

#### 4.2.1 East Ward — **Personal Matters / Ex. 6**

It was estimated that **Personal Matters / Ex. 6** Avenue needed thirteen (13) 500 mL samples to encompass the entire interior plumbing and service line prior to reaching the main. This home had a lead service line and lead solder with copper indoor plumbing and was sampled before the lead service line replacement (LSLR) and after the LSLR. A portion of the lead service line was sent to the EPA for a scale analysis following the first sequential sampling event. The following are the observations for the lead profile and water quality results for **Personal Matters / Ex. 6** Avenue, as shown in **Tables 4-1 and 4-2** and **Figures 4-2 and 4-3**.

- The highest lead levels at this address were found in the interior plumbing components, including the faucet hosing and piping directly connected to the faucet. For the first sequential sampling, before the LSLR, soluble lead peaked at 23.4 µg/L and total lead at 185 µg/L in the first sample (on the faucet hosing and interior plumbing components). For the second sequential sampling (post LSLR), soluble lead peaked at 19.8 µg/L in the 12<sup>th</sup> sample and the total lead peaked at 108 µg/L in the first sample.
- Significant particulate lead was found at this address in the first draw samples in both sequential sampling events. For the first sequential sampling, the aerator was removed on site prior to collecting samples but after flushing and stagnation. For the second sequential sampling, the aerator was removed prior to flushing and the stagnation period and remained off until sampling was completed.
- At the time of this report, the EPA has not been able to provide the results of the pipe scale analysis to confirm the stability of the scale on the lead service line.

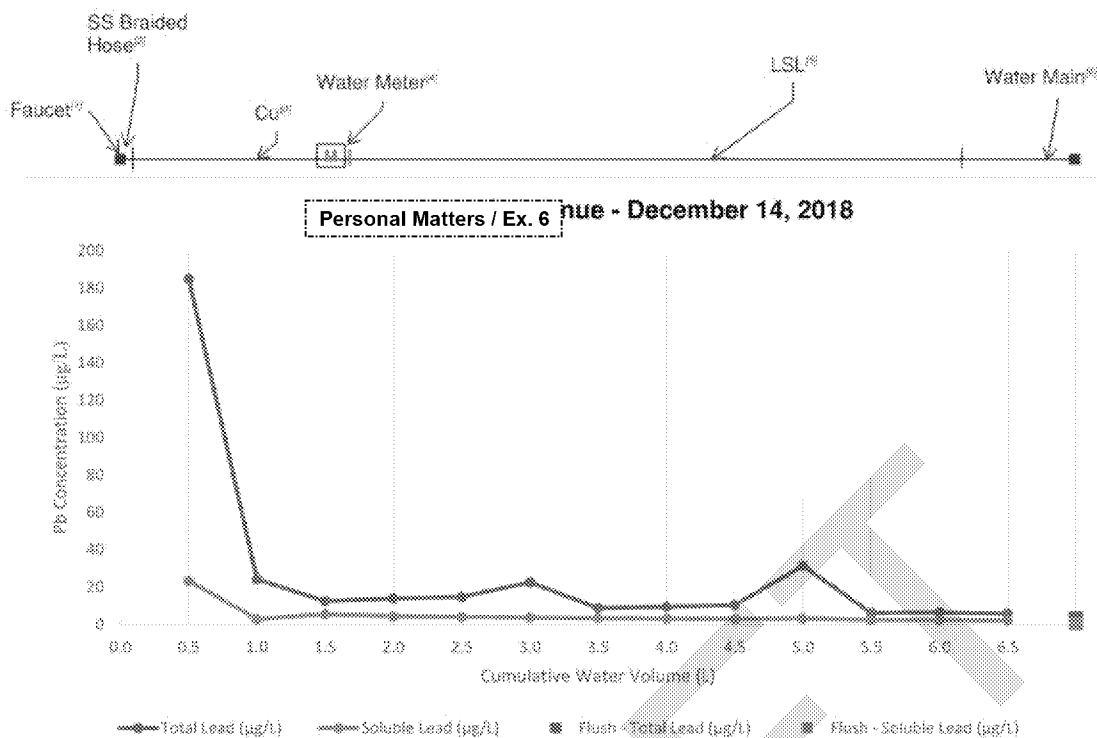
Table 4-1 – Water Quality Analysis at 95 Pennsylvania Avenue

Date of Sampling	Sample ID	pH <sup>[1]</sup>	Temp (deg C)	Free Cl <sub>2</sub> (mg/L)	Alkalinity (mg/L CaCO <sub>3</sub> )	Conductivity (uMhos/cm)	Silica (mg/L SiO <sub>2</sub> )	Orthophosphate (as P)
Before LSLR (12/14/18)	First Liter	N/A			33.0	251.0	3.75	0.396 (1.19 mg/L as PO <sub>4</sub> )
	Middle Samples				31.0	252.0	3.64	0.503 (1.51 mg/L as PO <sub>4</sub> )
	Flushed Sample				23.0	248.0	3.24	0.546 (1.64 mg/L as PO <sub>4</sub> )
After LSLR (1/19/19)	First Liter	6.97	15.0	0.04	34.0	215.0	N/A	0.739 (2.22 mg/L as PO <sub>4</sub> )
	Middle Samples	6.99	12.8	0.06	31.0	244.0		0.686 (2.06 mg/L as PO <sub>4</sub> )
	Flushed Sample	7.07	8.1	0.56	25.0	243.0		1.54 (4.62 mg/L as PO <sub>4</sub> )

<sup>[1]</sup>Values believed to be anomalous, see discussion section.

Table 4-2 – 95 Pennsylvania Avenue Lead Results

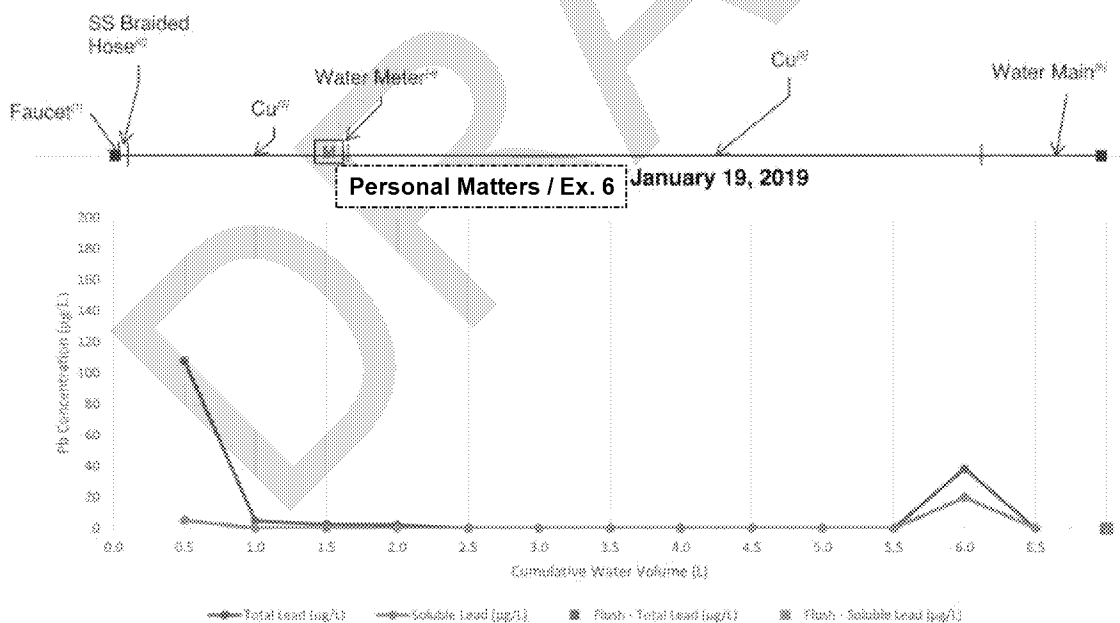
Sample ID	Before LSLR (12/14/2018)		After LSLR (01/19/2019)	
	Total Lead (µg/L)	Soluble Lead (µg/L)	Total Lead (µg/L)	Soluble Lead (µg/L)
1	185	23.4	108	5.24
2	24.2	2.86	4.75	< 2.0
3	12.5	5.52	2.40	< 2.0
4	13.8	4.41	2.06	< 2.0
5	14.7	4.00	< 2.0	< 2.0
6	22.6	3.63	< 2.0	< 2.0
7	8.68	3.37	< 2.0	< 2.0
8	9.53	3.07	< 2.0	< 2.0
9	10.3	2.94	< 2.0	< 2.0
10	31.4	3.31	< 2.0	< 2.0
11	6.14	2.38	< 2.0	< 2.0
12	6.43	2.21	38.3	19.8
13	5.74	2.04	< 2.0	< 2.0
Flushed	2.96	< 2.0	< 2.0	< 2.0



[1] Kitchen Faucet Location, [2] Stainless Steel Braided Hose, [3] Copper Pipe Segment, [4] Water Meter Location, [5] Lead Service Line Pipe Segment, [6] Water Main Location

Note: Lead levels below 2.0 µg/L are below the detection limit and are shown as 0 µg/L for graphical purposes.

**Figure 4-2 – Personal Matters / Ex. 6 Lead Profile – December 14, 2018**



[1] Kitchen Faucet Location, [2] Stainless Steel Braided Hose, [3] Copper Pipe Segment, [4] Water Meter Location, [5] New Copper Service Line Pipe Segment, [6] Water Main Location

Note: Lead levels below 2.0 µg/L are below the detection limit and are shown as 0 µg/L for graphical purposes.

**Figure 4-3 – Personal Matters / Ex. 6 Lead Profile – January 19, 2019**

- Silica concentrations were an average of 3.54 mg/L as SiO<sub>2</sub> for the first sequential sampling, which coincides with the Wanaque WQP ranges. The silica results for the second sequential sampling were unavailable at the time of this report.
- Orthophosphate measurements were an average of 1.45 mg/L as PO<sub>4</sub> for the first sequential sampling and 2.97 mg/L as PO<sub>4</sub> for the second sequential sampling, which coincides with the Wanaque WQPs measured in the distribution system. Note that the orthophosphate analysis was performed “out of hold,” or after the 48 hour required analysis time for a sample. It was performed within 72 hours of the sampling.
- Based on the water quality data collected at the tap, this location does not appear to be significantly influenced by the Pequannock Gradient water at the time of the sampling events even though it is located on the border of the two gradients.
- The total copper in the first sequential sampling results ranged from ND to the maximum value of 0.239 mg/L (9<sup>th</sup> sample). For the second sequential sampling, the total copper results ranged from ND to the maximum value of 0.350 mg/L (12<sup>th</sup> sample).
- The pH measurements were an average of 7.01 in the sequential sampling event, which is lower than the Wanaque WQPs measured in the distribution system. pH readings were collected in the field and are significantly lower than what would be expected based on WQP sampling as well as routine monitoring of the POE pH by the NJDWSC. pH measurement is seemingly simple, but in reality there are significant efforts beyond routine calibration required to obtain consistently accurate results. Electrodes can easily become scratched, deteriorated, or accumulate debris and require careful handling and storage. Subsequent testing of pH with 3 different electrodes at several locations found that one of three electrodes consistently produced significantly lower pH readings, while the remaining two electrodes provided pH readings within the range expected (7.0 to 7.7). As such, it is suspected that the low pH readings found during the sequential sampling are erroneous.
- The flow rate was measured on site during the sampling. The first sampling event occurred using a flow rate of 0.51 gpm and the second sampling occurred using a flowrate of 0.45 gpm.
- After flushing the water at the faucet for 10 minutes, the soluble lead was non-detect (ND), and the total lead was 2.96 µg/L for the first sequential sampling. After the service line was replaced, both the soluble lead and total lead concentrations were ND in the flushed sample.

#### 4.2.2 North Ward — Personal Matters / Ex. 6

It was estimated that Personal Matters / Ex. 6 needed twenty (20) 500 mL samples to encompass the entire interior plumbing and service line prior to reaching the main. This home had a lead service line and did not have lead solder found on the copper indoor plumbing before the meter. This location was sampled before and after the LSLR. A portion of the lead service line was sent to the EPA for a scale analysis. The following are the observations for the lead profile results for 14 Hinsdale Place, as shown in **Tables 4-3 and 4-4** and **Figures 4-4 and 4-5**.

**Table 4-3 – Water Quality Analysis at 1** Personal Matters / Ex. 6

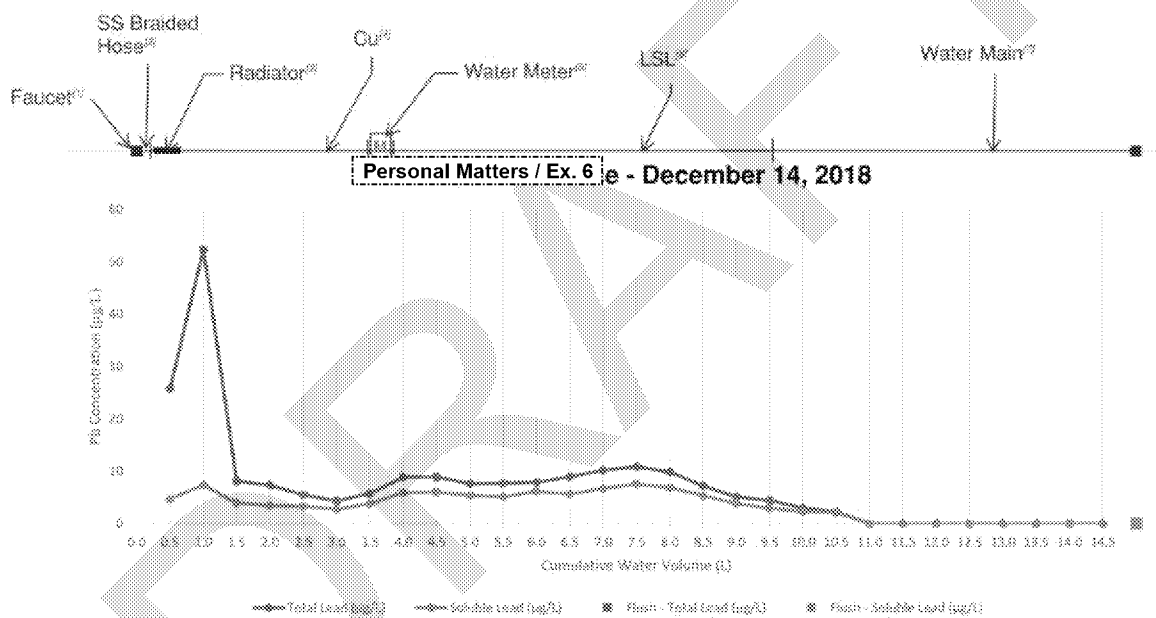
Date of Sampling	Sample ID	pH <sup>(1)</sup>	Temp (deg C)	Free Cl <sub>2</sub> (mg/L)	Alkalinity (mg/L CaCO <sub>3</sub> )	Conductivity (uMhos/cm)	Silica (mg/L SiO <sub>2</sub> )	Orthophosphate (as p) <sup>(2)</sup>
Before LSLR (12/14/18)	First Liter Sample	N/A			42.0	225.0	6.41	< 0.1 (< 0.3 mg/L as PO <sub>4</sub> )
	Middle Samples				28.0	210.0	6.48	< 0.1 (< 0.3 mg/L as PO <sub>4</sub> )
	Flushed Sample				28.0	214.0	6.57	< 0.1 (< 0.3 mg/L as PO <sub>4</sub> )
After LSLR (1/19/19)	First Liter Sample	6.76	15.1	0.06	27.0	214.0	N/A	< 0.1 (< 0.3 mg/L as PO <sub>4</sub> )
	Middle Samples	6.90	9.9	0.03	31.0	202.0		< 0.1 (< 0.3 mg/L as PO <sub>4</sub> )
	Flushed Sample	6.82	8.9	0.98	30.0	211.0		0.702 (2.11 mg/L as PO <sub>4</sub> )

<sup>(1)</sup> Values believed to be anomalous, see discussion section.**Table 4-4 –** Personal Matters / Ex. 6 **Lead Results**

Sample ID	Before LSLR (12/14/2018)		After LSLR (01/19/2019)	
	Total Lead (µg/L)	Soluble Lead (µg/L)	Total Lead (µg/L)	Soluble Lead (µg/L)
1	25.8	4.72	13.1	2.78
2	52.4	7.35	9.11	3.23
3	8.11	3.95	5.18	< 2.0
4	7.34	3.44	17.0	< 2.0
5	5.49	3.34	5.6	< 2.0
6	4.37	2.75	5.64	2.23
7	5.75	3.83	6.39	2.67
8	8.91	5.96	4.61	< 2.0
9	8.91	5.99	2.38	< 2.0
10	7.65	5.44	< 2.0	< 2.0
11	7.73	5.13	< 2.0	< 2.0
12	7.9	6.16	< 2.0	< 2.0
13	8.97	5.66	< 2.0	< 2.0
14	10.2	6.73	< 2.0	< 2.0
15	10.9	7.56	< 2.0	< 2.0
16	9.88	6.87	2.69	< 2.0
17	7.23	5.36	< 2.0	< 2.0
18	5.08	3.87	< 2.0	< 2.0

Sample ID	Before LSLR (12/14/2018)		After LSLR (01/19/2019)	
	Total Lead (µg/L)	Soluble Lead (µg/L)	Total Lead (µg/L)	Soluble Lead (µg/L)
19	4.43	2.96	< 2.0	< 2.0
20	3.00	2.34	< 2.0	< 2.0
21	2.3	2.15	< 2.0	7.68 <sup>[1]</sup>
22	2.04	< 2.0	< 2.0	< 2.0
23	< 2.0	< 2.0	< 2.0	< 2.0
24	< 2.0	< 2.0	< 2.0	7.44 <sup>[1]</sup>
25	< 2.0	< 2.0	< 2.0	< 2.0
26	< 2.0	< 2.0	< 2.0	< 2.0
27	< 2.0	< 2.0	< 2.0	< 2.0
28	< 2.0	< 2.0	< 2.0	< 2.0
29	< 2.0	< 2.0	< 2.0	< 2.0
FLUSH	< 2.0	< 2.0	< 2.0	14.4 <sup>[1]</sup>

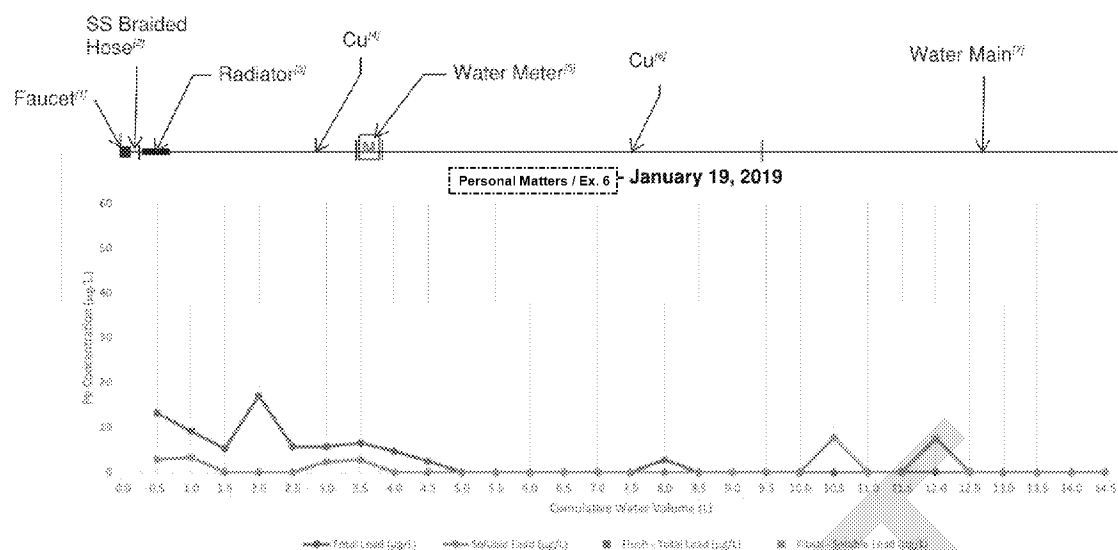
<sup>[1]</sup> Original testing of samples resulted in soluble lead greater than total lead which is not plausible.



<sup>[1]</sup> Kitchen Faucet Location, <sup>[2]</sup> Stainless Steel Braided Hose, <sup>[3]</sup> Approximate Radiator Location Under Copper Pipe Segment, <sup>[4]</sup> Copper Pipe Segment, <sup>[5]</sup> Water Meter Location, <sup>[6]</sup> Lead Service Line Pipe Segment, <sup>[7]</sup> Water Main Location

Note: Lead levels below 2.0 µg/L are below the detection limit and are shown as 0 µg/L for graphical purposes.

Figure 4-4 – Personal Matters / Ex. 6 Lead Profile – December 14, 2018



<sup>[1]</sup> Kitchen Faucet Location, <sup>[2]</sup> Stainless Steel Braided Hose, <sup>[3]</sup> Approximate Radiator Location Under Copper Pipe Segment, <sup>[4]</sup> Copper Pipe Segment, <sup>[5]</sup> Water Meter Location, <sup>[6]</sup> New Copper Service Line Pipe Segment, <sup>[7]</sup> Water Main Location

Note: Lead levels below 2.0 µg/L are below the detection limit and are shown as 0 µg/L for graphical purposes.

**Figure 4-5 – Personal Matters / Ex. 6 Lead Profile – January 19, 2019**

- The highest lead levels at this address were found in the interior plumbing components, including the faucet hosing and piping connected to the faucet. For the first sequential sampling, before the LSLR, the soluble lead peaked at 7.35 µg/L and total lead at 52.4 µg/L in the second sample (in the interior plumbing components after the faucet). For the second sequential sampling, after the LSLR, soluble lead peaked at 14.4 µg/L in the flushed sample and the total lead peaked at 17 µg/L in the fourth sample.
- Elevated amounts of particulate lead were found at this address the interior plumbing. For the first sequential sampling, the aerator was removed prior to collecting samples, but after flushing and stagnation. For the second sequential sampling, the aerator was removed prior to flushing and the stagnation period and remained off until sampling was completed. There was a slight increase in particulate lead right before reaching the water main and elevated amounts of dissolved lead in the flushed samples (samples 21, 24 and 30). The samples where the soluble lead is greater than the total lead is not plausible and will be re-tested and included in the update of this draft report.
- At the time of this report, the EPA has not been able to provide the results of the pipe scale analysis to confirm the stability of the scale on the lead service line.
- Silica concentrations were an average of 6.45 mg/L as SiO<sub>2</sub> for the first sequential sampling, which does not coincide with the Wanaque WQPs measured at the Belleville Reservoir, but rather with the average WQPs for the Pequannock service area. The silica results for the second sequential sampling were unavailable at the time of this report.



- All orthophosphate results were less than 0.3 mg/L as PO<sub>4</sub> for the first sequential sampling. For the second sequential sampling event, the orthophosphate results were less than 0.3 mg/L as PO<sub>4</sub> in the internal plumbing samples and the orthophosphate level was 2.11 mg/L as PO<sub>4</sub> in the flushed sample. The second sequential sampling orthophosphate result in the flushed sample coincides with the Wanaque WQPs measured in the distribution system. However, the interior plumbing orthophosphate results and the flushed sample in the first sequential sampling event does not coincide with the Wanaque WQPs measured in the distribution system indicating potential intermittent supplementation by the Pequannock water. Newark performed additional sampling at a hydrant on Hinsdale Place on January 30, 2019 which resulted in an orthophosphate level of 0.75 mg/L as PO<sub>4</sub>. Note that the orthophosphate analysis was performed “out of hold,” or after the 48 hour required analysis time for a sample in the first sequential sampling event.
- Based on the water quality data collected at the tap, this location appears to be influenced by the Pequannock Gradient water at the time of the sampling events.
- The total copper results for the first sequential sampling ranged from ND to the maximum value of 0.296 mg/L (2<sup>nd</sup> sample). For the second sequential sampling, the total copper results ranged from 0.11 mg/L to the maximum value of 1.65 mg/L (10<sup>th</sup> sample).
- The pH measurements averaged 6.82, which is lower than the Wanaque WQPs measured in the distribution system. pH readings were collected in the field and are significantly lower than what would be expected based on WQP sampling as well as routine monitoring of the POE pH by the NJDWSC. As mentioned above in the discussion in Section 4.2.1, it is suspected that the low pH readings found during the sequential sampling are erroneous.
- The flow rate was measured on site during the sampling. The first sampling event occurred using a flow rate of 0.64 gpm and the second sequential sampling had a flow rate of 1.60 gpm.
- The pH, temperature and chlorine residual were unable to be tested on site for the first sequential sampling. However, the temperature of the first 9 samples was fairly warm. During the site audit, a radiator was found to be located directly underneath a portion of the copper line in the basement. The radiator appears to be the source of the temperature increase and has an impact on soluble and insoluble lead levels as warmer water increases lead levels in drinking water.
- After flushing the water at the faucet for 10 minutes, both the soluble lead and total lead results were ND in the first sequential sampling. After the service line was replaced, the soluble lead concentration was 14.1 µg/L and the total lead was ND in the flushed sample. The samples where the soluble lead is greater than the total lead are not plausible and if re-tested, will be included in the update of this draft report.

#### 4.2.3 East Ward – **Personal Matters / Ex. 6**

It was estimated that **Personal Matters / Ex. 6** needed thirteen (13) 500 mL samples to encompass the entire interior plumbing and service line prior to reaching the main. This home had a lead service line and lead solder with copper indoor plumbing before the meter. The following are the

observations for the lead profile results for **Personal Matters / Ex. 6** as shown in **Tables 4-5** and **4-6** and **Figure 4-6**. It should be noted that some samples were re-tested for quality assurance. Both sample results, when applicable, are provided in **Table 4-6**.

**Table 4-5 – Water Quality Analysis at **Personal Matters / Ex. 6** Street**

Sample ID	pH <sup>[1]</sup>	Temp (deg C)	Free Cl <sub>2</sub> (mg/L)	Alkalinity (mg/L CaCO <sub>3</sub> )	Conductivity (uMhos/cm)	Silica (mg/L SiO <sub>2</sub> )	Orthophosphate (as P) <sup>[2]</sup>
First Liter	6.50	16.1	0.10	31.0	242.0	3.55	0.741 (2.22 mg/L as PO <sub>4</sub> )
Middle Samples	6.48	16.6	0.29	30.0	239.0	3.73	0.800 (2.40 mg/L as PO <sub>4</sub> )
Flushed Sample	6.62	16.0	0.62	30.0	241.0	3.64	0.749 (2.25 mg/L as PO <sub>4</sub> )

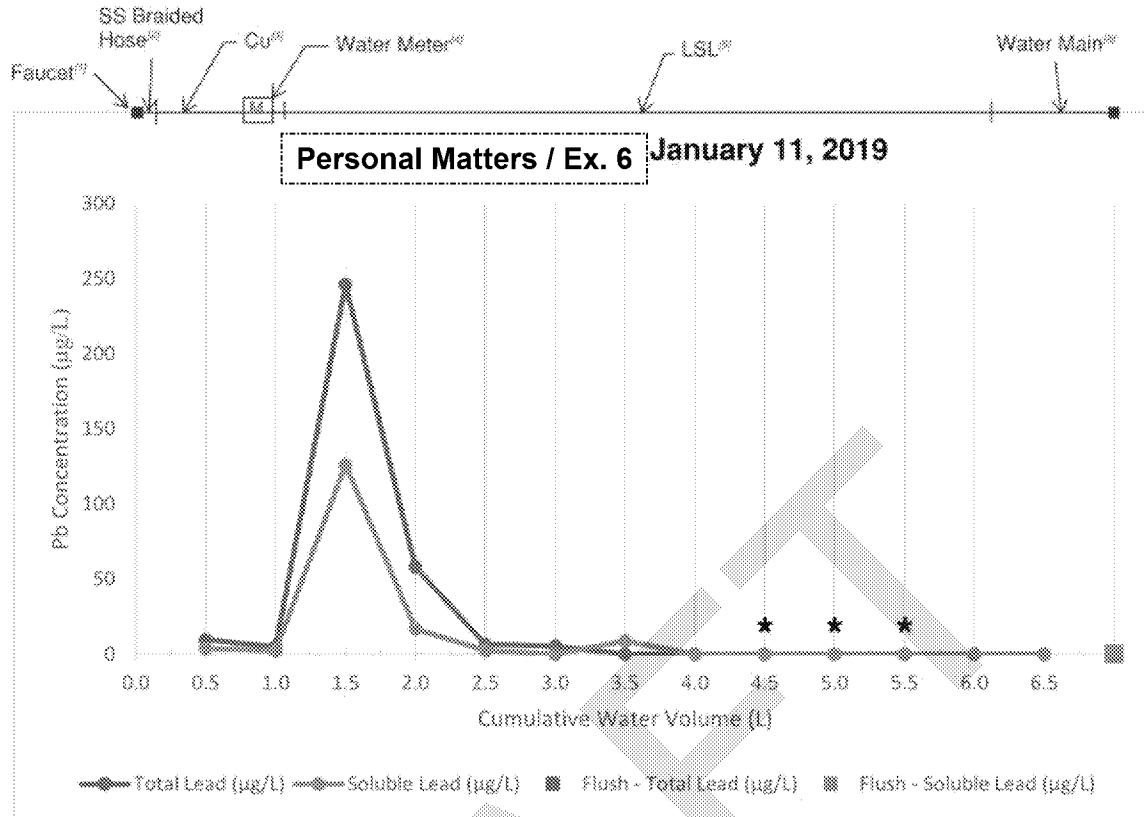
<sup>[1]</sup> Values believed to be anomalous, see discussion section.

**Table 4-6 – **Personal Matters / Ex. 6** Tap Lead Results**

Sample ID	Total Lead (µg/L)	Soluble Lead (µg/L)
1	9.72	3.86
2	4.95	2.52
3	246	126
4	58.2	17
5	6.56	2.5
6	5.28	< 2.0
7	< 2.0	8.88 <sup>[2]</sup>
8	< 2.0	< 2.0
9	< 2.0	< 2.0
10	< 2.0	< 2.0 (261) <sup>[1]</sup>
11	< 2.0	< 2.0 (4.03) <sup>[1]</sup>
12	< 2.0	< 2.0 (2.38) <sup>[1]</sup>
13	< 2.0	< 2.0
Flushed	< 2.0	< 2.0

<sup>[1]</sup> Original testing of samples in parentheses (X) resulted in soluble lead greater than total lead which is not plausible. Samples were retested.

<sup>[2]</sup> Original testing of samples resulted in soluble lead greater than total lead which is not plausible.



<sup>[1]</sup> Kitchen Faucet Location, <sup>[2]</sup> Stainless Steel Braided Hose, <sup>[3]</sup> Copper Pipe Segment, <sup>[4]</sup> Water Meter Location, <sup>[5]</sup> Lead Service Line Pipe Segment, <sup>[6]</sup> Water Main Location

\*Result shown was from re-tested sample. Original result indicated soluble lead greater than total lead which is not plausible. Both results are provided in the table.

Note: Lead levels below 2.0 µg/L are below the detection limit and are shown as 0 µg/L for graphical purposes.

**Figure 4-6 Personal Matters / Ex. 6 Lead Profile – January 11, 2019**

- The highest lead levels at this address were found in the interior plumbing components, including the faucet hosing and piping connected to the faucet. The aerator was connected to the faucet fixture and was unable to be removed for flushing and sampling. Soluble lead originally peaked at 261 µg/L in the 10<sup>th</sup> sample (which was shown to be greater than total lead), but after re-testing the sample it was determined to be ND. The updated results determined that the soluble lead peaked at 126 µg/L and total lead peaked at 246 µg/L in the third sample, which represents the copper piping before the meter through a portion of the lead service line and includes the water meter and brass fittings. The samples where the soluble lead is greater than the total lead are not plausible and, if re-tested, will be included in the update of this draft report.
- Elevated particulate lead was found at this address in the third sample.
- Silica concentrations were an average of 3.64 mg/L as SiO<sub>2</sub>, which coincides with the Wanaque WQP ranges.

- Orthophosphate measurements were an average of 2.29 mg/L as PO<sub>4</sub>, which coincides with the Wanaque WQP ranges.
- Based on the water quality data collected at the tap, this location does not appear to be significantly influenced by the Pequannock Gradient water at the time of sampling event.
- The total copper results ranged from ND to the maximum value of 0.224 mg/L (found in the 3<sup>rd</sup> sample).
- The pH measurements were an average of 6.53, which is lower than the WQPs measured in the Wanaque distribution system. pH readings were collected in the field and are significantly lower than what would be expected based on WQP sampling as well as routine monitoring of the POE pH by the NJDWSC. As mentioned above in the discussion in Section 4.2.1, it is suspected that the low pH readings found during the sequential sampling are erroneous.
- The flow rate was measure on site during the sampling and the samples were collected at a flow rate of 1.28 gpm.
- After flushing the water at the faucet for 10 minutes, both the soluble lead and total lead concentrations were ND in the flushed sample.

#### 4.2.4 East Ward – **Personal Matters / Ex. 6**

It was estimated that **Personal Matters / Ex. 6** needed ten (10) 500 mL samples to encompass the entire interior plumbing and service line prior to reaching the main. This home had a lead service line and there was no lead solder found on the copper indoor plumbing before the meter. The following are the observations for the lead profile results for **Personal Matters / Ex. 6**, as shown in **Tables 4-7 and 4-8** and **Figure 4-7**.

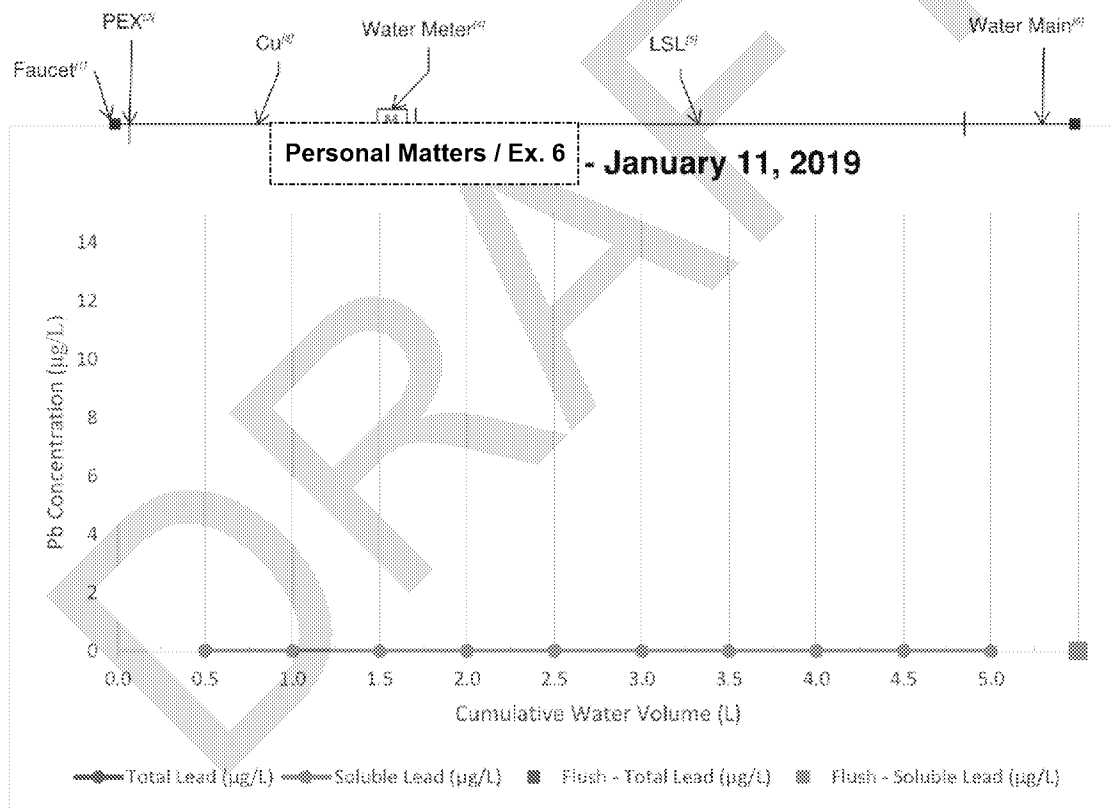
**Table 4-7 – Water Quality Analysis at: **Personal Matters / Ex. 6** Street**

Sample ID	pH <sup>[1]</sup>	Temp (deg C)	Free Cl <sub>2</sub> (mg/L)	Alkalinity (mg/L CaCO <sub>3</sub> )	Conductivity (uMhos/cm)	Silica (mg/L SiO <sub>2</sub> )	Orthophosphate (as P) <sup>[2]</sup>
First Liter	6.25	17.4	0.03	32.0	243.0	3.46	0.663 (1.99 mg/L as PO <sub>4</sub> )
Middle Samples	6.30	18.0	0.14	32.0	242.0	3.76	0.705 (2.16 mg/L as PO <sub>4</sub> )
Flushed Sample	6.36	20.0	0.36	31.0	240.0	3.75	0.700 (2.10 mg/L as PO <sub>4</sub> )

<sup>[1]</sup> Values believed to be anomalous, see discussion section.

**Table 4-8 – Personal Matters / Ex. 6 Kitchen Faucet Lead Results**

Sample ID	Total Lead (µg/L)	Soluble Lead (µg/L)
1	< 2.0	< 2.0
2	< 2.0	< 2.0
3	< 2.0	< 2.0
4	< 2.0	< 2.0
5	< 2.0	< 2.0
6	< 2.0	< 2.0
7	< 2.0	< 2.0
8	< 2.0	< 2.0
9	< 2.0	< 2.0
10	< 2.0	< 2.0
Flushed	< 2.0	< 2.0



<sup>[1]</sup> Kitchen Faucet Location, <sup>[2]</sup> Cross-Linked Polyethylene Pipe Segment, <sup>[3]</sup> Copper Pipe Segment, <sup>[4]</sup> Water Meter Location, <sup>[5]</sup> Lead Service Line Pipe Segment, <sup>[6]</sup> Water Main Location

Note: Lead levels below 2.0 µg/L are below the detection limit and are shown as 0 µg/L for graphical purposes.

**Figure 4-7 – Personal Matters / Ex. 6 Kitchen Faucet Lead Profile – January 11, 2019**

- There was no lead detected in any of the samples at this address.
- The aerator was connected to the faucet fixture and was unable to be removed for flushing and sampling.
- Silica concentrations were an average of 3.70 mg/L as SiO<sub>2</sub>, which coincides with the Wanaque WQP ranges.
- Orthophosphate measurements were an average of 2.08 mg/L as PO<sub>4</sub>, which coincides with the Wanaque WQP ranges.
- Based on the water quality data collected at the tap, this location does not appear to be significantly influenced by the Pequannock Gradient water at the time of the sampling event.
- The total copper results were ND for all samples.
- The pH measurements were an average of 6.30, which is lower than the Wanaque WQPs measured in the distribution system. pH readings were collected in the field and are significantly lower than what would be expected based on WQP sampling as well as routine monitoring of the POE pH by the NJDWSC. As mentioned above in the discussion in Section 4.2.1, it is suspected that the low pH readings found during the sequential sampling are erroneous.
- The flow rate was measure on site during the sampling and the samples were collected at a flow rate of 0.98 gpm.
- After flushing the water at the faucet for 10 minutes, both the soluble lead and total lead concentrations were ND in the flushed sample.

#### 4.2.5 East Ward – Personal Matters / Ex. 6

It was estimated that Personal Matters / Ex. 6 needed twenty (20) 500 mL samples to encompass the entire interior plumbing and service line prior to reaching the main. This home had a lead service line and lead solder with copper indoor plumbing before the meter. The following are the observations for the lead profile results for Personal Matters / Ex. 6 tap, as shown in **Tables 4-9** and **4-10** and **Figure 4-8**. It should be noted that some samples were re-tested for quality assurance. Both sample results, when applicable, are provided in **Table 4-10**.

Table 4-9 – Water Quality Analysis at **Personal Matters / Ex. 6** Street

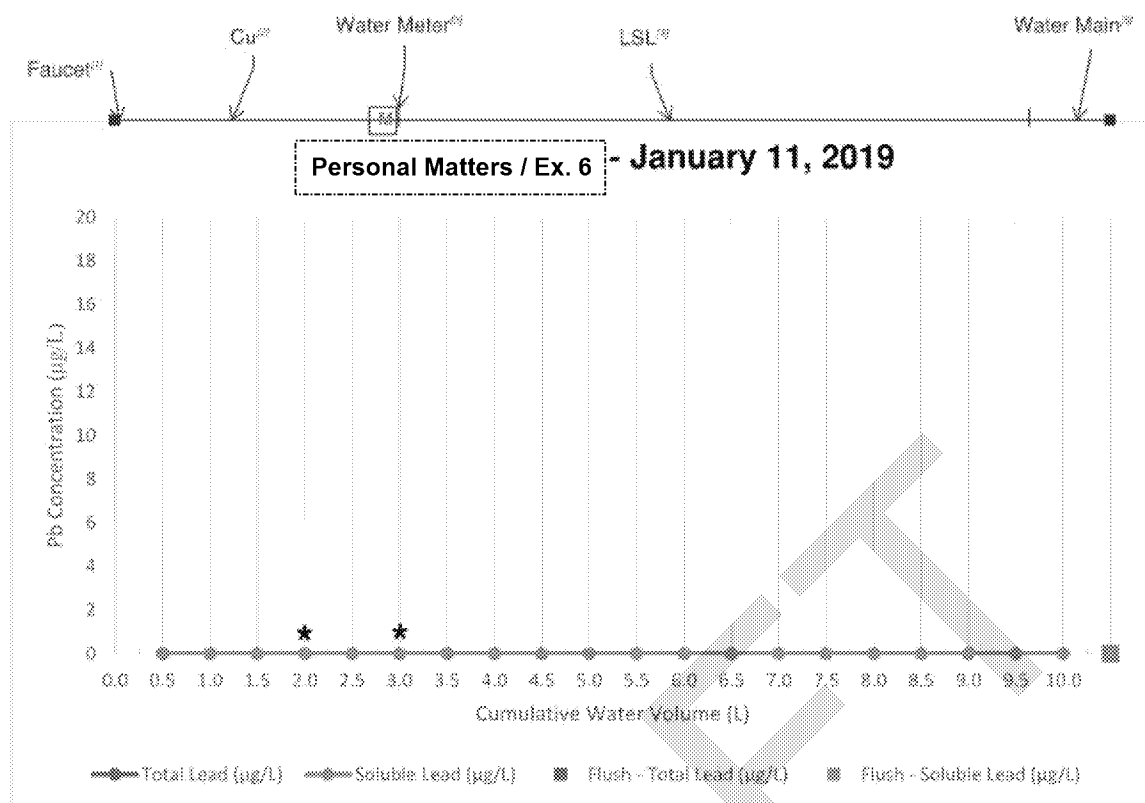
Sample ID	pH <sup>[1]</sup>	Temp (deg C)	Free Cl <sub>2</sub> (mg/L)	Alkalinity (mg/L CaCO <sub>3</sub> )	Conductivity (uMhos/cm)	Silica (mg/L SiO <sub>2</sub> )	Orthophosphate (as P) <sup>[2]</sup>
First Liter	6.53	19.1	0.21	30.0	242.0	3.90	0.710 (2.13 mg/L as PO <sub>4</sub> )
Middle Samples	6.31	18.8	0.35	30.0	238.0	3.80	0.714 (2.14 mg/L as PO <sub>4</sub> )
Flushed Sample	6.30	18.2	0.53	30.0	233.0	3.72	0.715 (2.15 mg/L as PO <sub>4</sub> )

<sup>[1]</sup> Values believed to be anomalous, see discussion section.

Table 4-10 **Personal Matters / Ex. 6** Lead Results

Sample ID	Total Lead (µg/L)	Soluble Lead (µg/L)
1	< 2.0	< 2.0
2	< 2.0	< 2.0
3	< 2.0	< 2.0
4	< 2.0 (5.62) <sup>[1]</sup>	< 2.0 (17.9) <sup>[1]</sup>
5	< 2.0	< 2.0
6	< 2.0	< 2.0 (4.84) <sup>[1]</sup>
7	< 2.0	< 2.0
8	< 2.0	< 2.0
9	< 2.0	< 2.0
10	< 2.0	< 2.0
11	< 2.0	< 2.0
12	< 2.0	< 2.0
13	< 2.0	< 2.0
14	< 2.0	< 2.0
15	< 2.0	< 2.0
16	< 2.0	< 2.0
17	< 2.0	< 2.0
18	< 2.0	< 2.0
19	< 2.0	< 2.0
20	< 2.0	< 2.0
Flushed	< 2.0	< 2.0

<sup>[1]</sup> Original testing of samples in parentheses (X) resulted in soluble lead greater than total lead which is not plausible. Samples were retested.



<sup>[1]</sup> Kitchen Faucet Location, <sup>[2]</sup> Copper Pipe Segment, <sup>[3]</sup> Water Meter Location, <sup>[4]</sup> Lead Service Line Pipe Segment, <sup>[5]</sup> Water Main Location

\*Result shown was from re-tested sample. Original result indicated soluble lead greater than total lead which is not plausible. Both results are provided in the table.

Note: Lead levels below 2.0 µg/L are below the detection limit and are shown as 0 µg/L for graphical purposes.

**Figure 4-8 – Personal Matters / Ex. 6 Lead Profile – January 11, 2019**

- There was no lead detected in any of the samples at this address. Originally, the highest lead levels at this address were found in the interior plumbing components, including the faucet and piping connected to the faucet. Soluble lead originally peaked at 17.9 µg/L and total lead peaked at 5.62 µg/L in the fourth sample, which represents the copper line in the premise plumbing. However, after re-testing, the amount of lead was found to be ND in all samples. It is not possible for soluble lead to be greater than total lead.
- The aerator was removed before collecting samples.
- Silica concentrations were an average of 3.80 mg/L as SiO<sub>2</sub>, which coincides with the Wanaque WQP ranges.
- Orthophosphate measurements were an average of 2.14 mg/L as PO<sub>4</sub>, which coincides with the Wanaque WQP ranges.
- Based on the water quality data collected at the tap, this location does not appear to be significantly influenced by the Pequannock Gradient water at the time of the sampling events.



- The total copper results were ND for all samples.
- The pH measurements were an average of 6.39, which is lower than the Wanaque WQPs measured in the distribution system. pH readings were collected in the field and are significantly lower than what would be expected based on WQP sampling as well as routine monitoring of the POE pH by the NJDWSC. As mentioned above in the discussion in Section 4.2.1, it is suspected that the low pH readings found during the sequential sampling are erroneous.
- The flow rate was measure on site during the times of sampling and the samples were collected at a flow rate of 1.28 gpm.
- After flushing the water at the faucet for 10 minutes, both the soluble lead and total lead concentrations were ND in the flushed sample.

#### 4.2.6 East Ward – **Personal Matters / Ex. 6** Street

It was estimated that **Personal Matters / Ex. 6** needed seventeen (17) 500 mL samples to encompass the entire interior plumbing and service line prior to reaching the main. This home had a lead service line and lead solder with copper indoor plumbing before the meter. The following are the observations for the lead profile results for 63 ½ Garrison Street, as shown in **Tables 4-11** and **4-12** and **Figure 4-9**.

- The total lead peaked at 3.97 µg/L in the first sample, which represents the interior plumbing components, including the faucet hosing and piping connected to the faucet. There was no soluble lead detected in any of the samples at this address. The aerator was removed on site before collecting samples.
- There was a slight amount in particulate lead found in the sixth and seventh samples. These samples represent the lead service line located before the curb box.
- Silica concentrations were an average of 3.55 mg/L as SiO<sub>2</sub>, which coincides with the Wanaque WQP ranges.
- Orthophosphate measurements were an average of 2.15 mg/L as PO<sub>4</sub>, which coincides with the Wanaque WQP ranges.
- Based on the water quality data collected at the tap, this location does not appear to be significantly influenced by the Pequannock Gradient water at the time of the sampling events.
- The total copper results ranged from ND to the maximum value of 0.0501 mg/L (first sample).
-

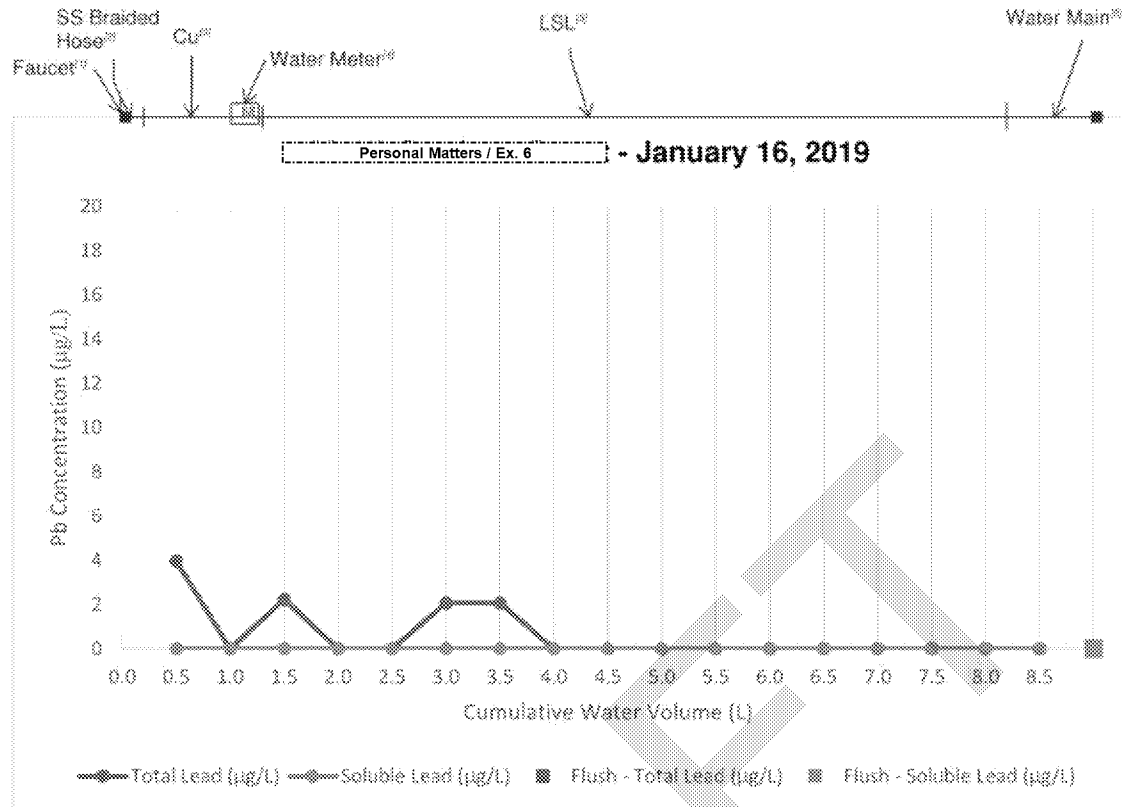
**Table 4-11 – Water Quality Analysis at [Personal Matters / Ex. 6]**

Sample ID	pH <sup>[1]</sup>	Temp (deg C)	Free Cl <sub>2</sub> (mg/L)	Alkalinity (mg/L CaCO <sub>3</sub> )	Conductivity (uMhos/cm)	Silica (mg/L SiO <sub>2</sub> )	Orthophosphate (as P) <sup>[2]</sup>
First Liter	6.62	20.3	0.16	36.0	234.0	3.86	0.708 (2.12 mg/L as PO <sub>4</sub> )
Middle Samples	6.56	18.5	0.65	32.0	232.0	3.63	0.718 (2.15 mg/L as PO <sub>4</sub> )
Flushed Sample	6.61	15.7	0.69	29.0	210.0	3.15	0.728 (2.18 mg/L as PO <sub>4</sub> )

<sup>[1]</sup> Values believed to be anomalous, see discussion section.

**Table 4-12 – [Personal Matters / Ex. 6] Lead Results**

Sample ID	Total Lead (µg/L)	Soluble Lead (µg/L)
1	3.97	< 2.0
2	< 2.0	< 2.0
3	2.23	< 2.0
4	< 2.0	< 2.0
5	< 2.0	< 2.0
6	2.07	< 2.0
7	2.07	< 2.0
8	< 2.0	< 2.0
9	< 2.0	< 2.0
10	< 2.0	< 2.0
11	< 2.0	< 2.0
12	< 2.0	< 2.0
13	< 2.0	< 2.0
14	< 2.0	< 2.0
15	< 2.0	< 2.0
16	< 2.0	< 2.0
17	< 2.0	< 2.0
Flushed	< 2.0	< 2.0



<sup>[1]</sup> Kitchen Faucet Location, <sup>[2]</sup> Stainless Steel Braided Hose, <sup>[3]</sup> Copper Pipe Segment, <sup>[4]</sup> Water Meter Location, <sup>[5]</sup> Lead Service Line Pipe Segment, <sup>[6]</sup> Water Main Location

Note: Lead levels below 2.0 µg/L are below the detection limit and are shown as 0 µg/L for graphical purposes.

**Figure 4-9** Personal Matters / Ex. 6 Lead Profile – January 16, 2019

- The pH measurements were an average of 6.60, which is lower than the Wanaque WQPs measured in the distribution system. pH readings were collected in the field and are significantly lower than what would be expected based on WQP sampling as well as routine monitoring of the POE pH by the NJDWSC. As mentioned above in the discussion in Section 4.2.1, it is suspected that the low pH readings found during the sequential sampling are erroneous.
- The flow rate was measure on site during the sampling and the samples were collected at a flow rate of 1.84 gpm.
- After flushing the water at the faucet for 10 minutes, both the soluble lead and total lead concentrations were ND in the flushed sample.

#### 4.2.7 North Ward – Personal Matters / Ex. 6

It was estimated that Personal Matters / Ex. 6 needed seventeen (17) 500 mL samples to encompass the entire interior plumbing and service line prior to reaching the main. This home had a lead service line and lead solder on the copper indoor plumbing before the meter. The following are the

observations for the lead profile results for **Personal Matters / Ex. 6** as shown in **Tables 4-13** and **4-14** and **Figure 4-9**.

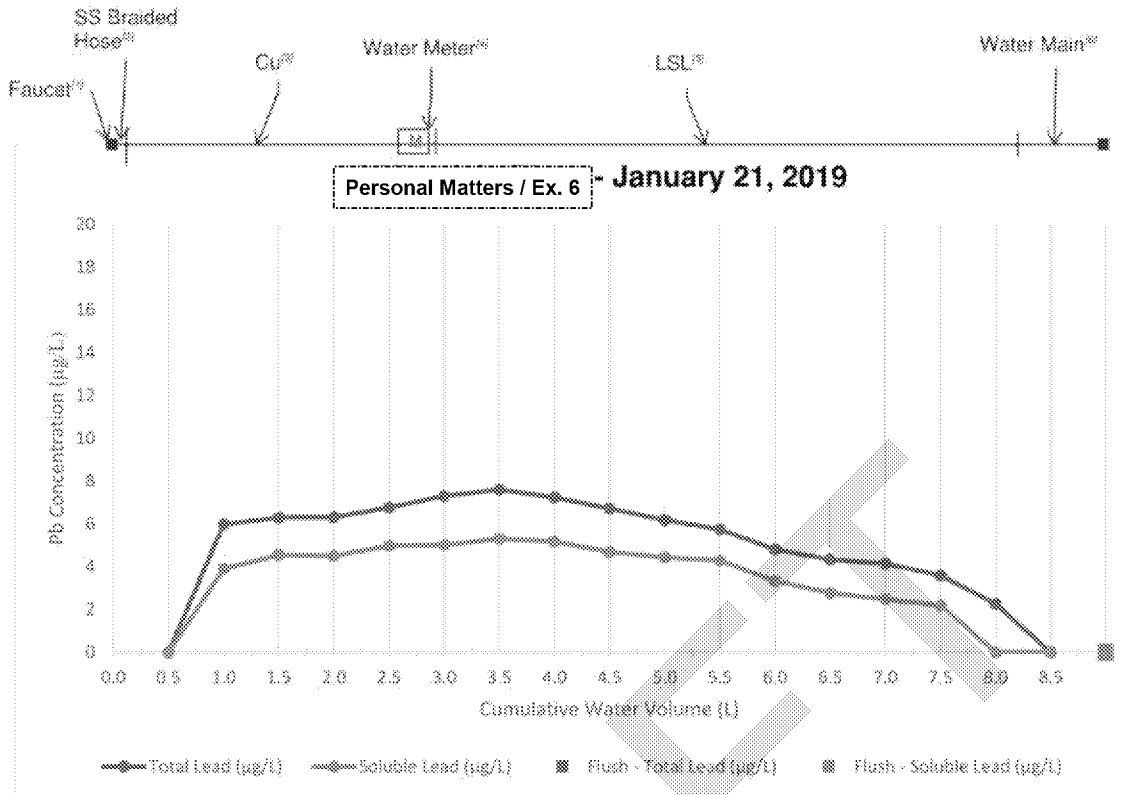
**Table 4-13 – Water Quality Analysis at **Personal Matters / Ex. 6****

Sample ID	pH <sup>[1]</sup>	Temp (deg C)	Free Cl <sub>2</sub> (mg/L)	Alkalinity (mg/L CaCO <sub>3</sub> )	Conductivity (uMhos/cm)	Silica (mg/L SiO <sub>2</sub> )	Orthophosphate (as P) <sup>[2]</sup>
First Liter	6.60	13.2	0.19	29.0	197.0	N/A	< 0.1 (< 0.3 mg/L as PO <sub>4</sub> )
Middle Samples	6.62	11.1	0.62	27.0	201.0		< 0.1 (< 0.3 mg/L as PO <sub>4</sub> )
Flushed Sample	6.63	9.18	0.67	28.0	203.0		0.768 (2.30 mg/L as PO <sub>4</sub> )

<sup>[1]</sup> Values believed to be anomalous, see discussion section.

**Table 4-14 – **Personal Matters / Ex. 6** Lead Results**

Sample ID	Total Lead (µg/L)	Soluble Lead (µg/L)
1	< 2.0	< 2.0
2	5.97	3.9
3	6.29	4.54
4	6.32	4.51
5	6.76	4.98
6	7.3	5.01
7	7.6	5.31
8	7.24	5.17
9	6.71	4.69
10	6.18	4.43
11	5.74	4.28
12	4.81	3.34
13	4.33	2.77
14	4.14	2.48
15	3.59	2.2
16	2.26	< 2.0
17	< 2.0	< 2.0
Flushed	< 2.0	< 2.0



<sup>[1]</sup> Kitchen Faucet Location, <sup>[2]</sup> Stainless Steel Braided Hose, <sup>[3]</sup> Copper Pipe Segment, <sup>[4]</sup> Water Meter Location, <sup>[5]</sup> Lead Service Line Pipe Segment, <sup>[6]</sup> Water Main Location

Note: Lead levels below 2.0 µg/L are below the detection limit and are shown as 0 µg/L for graphical purposes.

**Figure 4-10 – Lead Profile – January 21, 2019**

- The soluble lead at this address peaked at 5.31 µg/L and total lead peaked at 7.6 µg/L in the 7<sup>th</sup> sample, which represents where the copper piping transitions to the LSL and includes the meter and brass fittings.
- The silica concentrations were unavailable at the time of this report.
- The orthophosphate measurements of the samples representing the interior plumbing were both less than 0.3 mg/L as PO<sub>4</sub>, which does not coincide with the Wanaque WQPs measured in the distribution system and indicates potential supplementation by the Pequannock water. However, the flushed sample orthophosphate result of 2.30 mg/L as PO<sub>4</sub> coincides with the Wanaque WQPs measured in the distribution system. Newark performed additional sampling at a hydrant on Hinsdale Place on January 30, 2019 which resulted in an orthophosphate level of 0.75 mg/L as PO<sub>4</sub>.
- Based on the water quality data collected at the tap, this location appears to be influenced by the Pequannock Gradient water at the time of sampling events based on the orthophosphate sample results; however, this will be confirmed by the silica concentrations, which are not yet available.

- The total copper results ranged from 0.0161 mg/L up to the maximum value of 0.222 mg/L (first sample).
- The pH measurements were an average of 6.62, which is lower than the Wanaque WQPs measured in the distribution system. pH readings were collected in the field and are significantly lower than what would be expected based on WQP sampling as well as routine monitoring of the POE pH by the NJDWSC. As mentioned above in the discussion in Section 4.2.1, it is suspected that the low pH readings found during the sequential sampling are erroneous.
- The flow rate was measured on site during the times of sampling and occurred using a flow rate of 0.78 gpm.
- After flushing the water at the faucet for 10 minutes, both the soluble lead and total lead resulted as ND in the flushed sample.

### 4.3 Discussion

Lead sequential sampling was used in the Wanaque Gradient to compare with the previous sequential sampling performed in the Pequannock Gradient, to isolate the source(s) of lead in tap water in a given home, and to compare soluble and particulate lead as an indication of the stability of the protective scale. In addition, over time, lead sequential sampling can be used as a tool to monitor the effectiveness of CCT implementation or optimization.

It is important to recognize that both site specific and systemic factors may influence the lead levels measured at the water tap. Site specific factors include physical characteristics of the lead service line (length, diameter, surface area), water use patterns before and during sampling, piping configurations, hydraulic conditions, and manufacturing materials used for piping and fittings. Systemic factors include water quality, water pressure, scale formation and scale breakdown on the service line. These factors can contribute to variability in sampling results within the same water system and over time. At **Personal Matters / Ex. 6**

**Personal Matters / Ex. 6**, higher lead results were found in the interior plumbing or at the start of the lead service line during the sequential sampling. These results are consistent with other sequential sampling studies for systems with orthophosphate treatment that indicate peak lead concentrations often originate from the premise piping and/or the faucet, and not the lead service line where a stable orthophosphate scale may have formed.

#### 4.3.1 Differences Between LCR Compliance Sampling and Sequential Sampling

There are several major differences between LCR compliance sampling (with a Lead AL established at 15 µg/L) and the sequential sampling protocols that may result in the detection of higher lead levels than LCR compliance sampling. Some of the major differences are provided in **Table 4-15**.

**Table 4-15 – Key Differences Between LCR Compliance Sampling and Sequential Sampling Protocols**

Sampling Characteristic	LCR Compliance Sampling Protocol	Sequential Sampling Protocol	Potential Impact to Lead Results
<b>Sample Volume</b>	First Liter (1,000 mL)	500 mL samples throughout the entire service	Smaller volumes collected using the sequential sampling protocol can better identify the location of the source of the lead and can result in a higher value without dilution from a larger sample.
<b>Stagnation Period</b>	Minimum 6 hours stagnation	6-12 hours of stagnation	A stagnation period greater than 6 hours may increase soluble lead results with changing water quality and water may becoming more aggressive as it stagnates.
<b>Removing the Aerator</b>	Not removed during stagnation or sampling	Removed during sampling (when applicable)	Removing the aerator may increase the reported value of particulate lead because there is no screen to filter the particulates out of the water.
<b>Flushing Before Stagnation Period</b>	No flushing	Flushing before the stagnation period	Flushing before the stagnation period can stimulate migration of particulate lead that has settled throughout the plumbing which may result in higher particulate lead results in sequential sampling.
<b>Sampling Flow Rate</b>	Sampling flow rate should be similar to the flow rate used to fill a glass of water.	Sampling flow rate averaged approximately 1 gpm. This may be slightly higher than the LCR compliance sampling flow rate.	A higher flow rate may disturb settled particulate lead in the home plumbing and show up in the samples.
<b>Sampling Conducted by</b>	Homeowner	Laboratory technician	Sampling protocol procedures are more consistent for multiple sampling sites when one person (i.e. laboratory technician) is taking samples.

Varying lead results are not uncommon when comparing sequential sampling and LCR compliance sampling for systems that are in compliance with the LCR (i.e. 90<sup>th</sup> percentile of first liter samples below 15 µg/L). As an example, field studies using the sequential sampling method were conducted at drinking water taps in Seattle Public Schools. Results showed elevated lead levels in the first and second samples drawn, which indicated a release of lead likely originating from the water fountain bubbler head or associated fittings and components (Boyd, Pierson,

Kirmeyer, Britton, & English, 2006). These sample locations indicated lead results greater than the LCR Lead AL in the sequential sampling testing; however, Seattle has met LCR requirements in their distribution system since 2003.

#### 4.3.2 Samples with Soluble Lead Greater Than Total Lead

Soluble lead is tested by filtering out particulate lead from total lead samples. Both soluble lead samples and the total lead samples are acidified prior to testing. The acidification is done in soluble lead samples after the sample is filtered. Soluble lead and particulate lead should theoretically equal total lead.

A few samples in the sequential sampling process were initially reported by the laboratory to have soluble lead greater than total lead. This is clearly inaccurate. Most of the results in Section 4 that indicated soluble lead greater than total lead were retested. The samples that have been retested resulted in soluble lead less than total lead, as expected. Therefore, the samples that were retested were used in the analysis. The original sample values are shown on the tables only for information.

Although lead sampling does have a margin of error, some results indicated significant variations. The laboratory has been requested to provide an explanation for the variability in the results.

#### 4.3.3 Potential Causes of Lead Levels in Premise Plumbing

Lead was a component in solder on copper piping on interior, or premise, plumbing until it was banned in 1986. Brass components also contained significant lead content until 1986 when up to 8-percent of lead (by weight) was allowed to be classified as “lead-free”. In 2014, the “lead-free” limit was changed to 0.25-percent by weight by the EPA.

Lead results in premise plumbing after a stagnation period can be greater than lead results in a lead service line when the scale on a lead service line is stable and galvanic reactions between metals (i.e. lead solder and copper piping) or lead in brass fittings dominate the lead profile.

The smaller sampling volume utilized during sequential sampling can provide a better estimate of the source of lead levels in premise plumbing and the contribution of that source to the lead levels detected. Levels of lead that are found in the first few samples taken during sequential sampling may not be representative of the levels of lead seen from the one (1) liter sample required during LCR compliance testing.

The following factors may contribute to elevated levels of lead found in the first two (2) liters of sampling in the Wanaque Gradient samples:

- **Brass components in the premise plumbing or inline service line components.** While plumbing suppliers have now developed fixtures and other plumbing system components that contain no or low levels of lead, many homes in the Wanaque Gradient were constructed prior to 1986 and likely have premise plumbing components that contain brass with lead. Brass materials are known to cause “dezincification”. When dezincification occurs, zinc is released from the brass or alloyed material and the remaining lead and copper can react in water by galvanic corrosion, thus allowing further release of lead into the water (Boyd, Pierson, Kirmeyer, Britton, & English, 2006). Brass ferrules, which often



contain lead, are often found inside the stainless steel threaded hose connectors that attach the stainless steel braided hose under the sink to the faucet.

- **Faucets and immediate connective piping containing lead.** Faucets and immediate connective piping can provide a significant contribution of lead. The literature reports that faucets and immediate connective piping can contribute 5 to 31 percent of the lead in the first liter sample collected at the tap for LCR compliance testing (Sandvig, et al., 2008). In the case of faucets, variability in configuration and manufacturing can produce variations in lead content. Older faucets or decorative faucets can have higher lead content.
- **Flushing prior to the stagnation period during sequential sampling.** LCR sampling does not require flushing prior to collecting one-liter sample. At sites with lead service lines, fully flushed samples, such as in the sequential sampling, may contain measurable lead due to uptake of particulate lead as the water flows through the system to the tap. Therefore, measurable lead may be present in the background water at the start of the stagnation period for LCR sampling, further elevating lead levels after stagnation (Sandvig, et al., 2008).
- **Particulate lead in the aerator.** Because most of the samples in the sequential sampling were taken with the aerator off, particulate lead that may typically be screened was free to flow into the samples. This can be prevented by regularly cleaning aerators and flushing prior to using the water for drinking or cooking.
- **Inconsistent orthophosphate in the Wanaque Gradient.** It is believed that the zinc orthophosphate from NJDWSC is consistently supplied at an approximately 1.5 to 1.8 mg/L as PO<sub>4</sub> dose. Additional sampling is currently being performed to determine if the orthophosphate has been diluted from the Pequannock water.
- **Wanaque water supplemented by Pequannock water.** As discussed in Section 3.2.1, water from the Pequannock Gradient can enter the Wanaque Gradient through manual division gate valves and through automatic pressure regulating valves. Several areas were identified within the Wanaque Gradient that appear to have experienced diluted orthophosphate and higher silica values, indicating that they were likely influenced by the Pequannock Gradient. As of this initial draft report, there is no information from the LCR compliance sampling data that indicates areas likely influenced by the Pequannock Gradient are experiencing higher lead concentrations than other areas of the Wanaque Gradient not appearing to be influenced by the Pequannock Gradient.

#### 4.3.4 Comparison of Pequannock and Wanaque Sequential Sampling Results

In comparing only the highest lead concentration in the sequential sampling profiles, one would compare the results at some sites in the Wanaque Gradient (see **Personal Matters / Ex. 6**)

(see **Personal Matters / Ex. 6**) to the sequential sampling performed in the Pequannock Gradient at **Personal Matters / Ex. 6** Street in Newark, which had a peak lead value of 147 µg/L as presented in the October 2018 draft report. However, the major difference between the samples taken in the Wanaque Gradient and the samples taken in the Pequannock Gradient is that the Wanaque Gradient profiles consistently result in non-detect lead levels for the majority of the lead service line and for the flushed

samples. The two profiles performed in the Pequannock Gradient did not result in non-detect lead levels, even in the flushed samples from the water mains that do not contain lead. It was determined in that study that the scales on the lead service lines for those receiving Pequannock water are unstable, and therefore, water passing through the lead service lines is carrying particulate lead from the unstable scales and soluble lead from direct contact with the lead pipes to the tap. This was confirmed through the scale analyses performed by the EPA. As a result, flushing the service line, as generally recommended by the literature in reducing lead levels in drinking water, was deemed ineffective at reducing lead concentrations in the Pequannock Gradient. Based on the sequential sampling alone, it appears that flushing is an effective method in the Wanaque Gradient to reduce lead concentrations at the tap, and that the scale on the lead service line is stable and providing protection for residents. However, the results of the scale analysis are needed to confirm the stability of the protective scale on the lead service lines. An updated draft of this report will include the results of the EPA scale analysis and recommendations for any modifications to the current corrosion control treatment in the Wanaque Gradient.

## Section 5

### Scale Analysis

This section is pending EPA results.

DRAFT

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## Section 6

### Recommendations

Pending completion of analyses.

DRAFT

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## Appendix A

### Wanaque Pipe Scale Analysis

DRAFT

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